PB81-104176

EXEC/OP Reference Manual
Version 1.2

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

Jun 80

U.S. Department of Commerce
National Technical Information Service
NTIS

50272-101

REPORT DOCUMENTATION PAGE	**1. REPORT NO.** EPA/DF-80/009a EPA-600/2-80-182	**2.**	**3.** PB81-104176

4. Title and Subtitle
EXEC/OP Reference Manual, Version 1.2

5. Report Date
June 1980

6.

7. Author(s)
Lewis A. Rossman

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Municipal Environmental Research Laboratory --Cinti., Ohio
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

10. Project/Task/Work Unit No.
1BC821, SOS1

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
Same as above

13. Type of Report & Period Covered
Inhouse (Feb.-Mar. 1980)

14. EPA/600/14

15. Supplementary Notes
This report supplements "Computer-Aided Synthesis of Wastewater Treatment and Sludge Disposal Systems", EPA-600/2-79-158, December 1979 PB 80-174 220
Project Officer: Lewis A. Rossman 513/684-7636 For magnetic tape see: PB81-104168

16. Abstract (Limit: 200 words)

The original version of EXEC/OP, a FORTRAN computer program that synthesizes municipal wastewater treatment system designs from a specified list of unit treatment processes, has been updated. Revisions have been made in several of the unit process performance sub-models to produce results that conform more closely to accepted design practices. This new reference manual describes the elements of the EXEC/OP program, gives instructions on how to prepare input data for the program, and illustrates its application to a sample design problem. Also included is a listing of the updated FORTRAN source code and definitions of the program's variables. A computer tape of the FORTRAN source code is available through NTIS.

REPRODUCED BY
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

17. Document Analysis a. Descriptors
Waste treatment
Sludge disposal
Facilities
Systems Analysis
Optimization

b. Identifiers/Open-Ended Terms
Wastewater treatment
Waste treatment facilities
Sludge treatment
Treatment facilities
System synthesis
Multi-objective planning

c. COSATI Field/Group 13B

18. Availability Statement: Release to public	**19. Security Class (This Report)** Unclassified	**21. No. of Pages** 166
	20. Security Class (This Page) Unclassified	**22. Price**

(See ANSI-Z39.18)

See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

EPA-600/2-80-182a
June 1980

EXEC/OP REFERENCE MANUAL

Version 1.2

by

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MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and govenment concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

The work presented here describes the development and use of a computer-aided preliminary design procedure for wastewater treatment and sludge disposal systems. It enables a designer to efficiently synthesize and analyze large numbers of alternative treatment schemes and rank them with respect to several different cost, energy, and environmental criteria. Such a design tool should enhance our capability to develop more innovative and efficient waste treatment systems in these times of stricter environmental standards and increasing resource costs.

Francis T. Mayo
Director, Municipal Environmental
Research Laboratory

ABSTRACT

The original version of EXEC/OP, a FORTRAN computer program that synthesizes municipal wastewater treatment system designs from a specified list of unit treatment processes, has been updated. Revisions have been made in several of the unit process performance sub-models to produce results that conform more closely to accepted design practices. This new reference manual describes the elements of the EXEC/OP program, gives instructions on how to prepare input data for the program, and illustrates its application to a sample design problem. Also included is a listing of the updated FORTRAN source code and definitions of the program's variables. A computer tape of the FORTRAN source code is available through NTIS.

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ERRATA

EXEC/OP REFERENCE MANUAL.
VERSION 1.2

(EPA-600/2-80-182)

The following corrections should be made to this report, the computer program listing, and (if the computer tape is purchased) to the computer tape:

1. Page 82: Immediately after the line

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DO 115 K = 1,10
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add the line

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B(K) = 0.
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2. Page 95: Immediately after the line

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DO 5 I = 1,20
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add the line

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OMATX(I,N) = 0.
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3. Page 106: Immediately after the line

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DIMENSION RECYC(20)
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add the line

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FPS(J) = 0.
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4. Page 142: Delete the two lines that follow the statement labelled 140.

SECTION 1

INTRODUCTION

EXEC/OP is a FORTRAN computer program that synthesizes municipal wastewater treatment systems from a specified list of unit treatment processes. It can be thought of as an optimization version of a previously developed treatment system evaluation program known as EXECUTIVE [1]. EXEC/OP will select the combination of unit processes that approximately best meets a stipulated set of criteria on cost, energy, land utilization, a subjective index of system desirability, and effluent quality. It also has the capability to identify the M system designs that are within X% of the best.

The current version of EXEC/OP views a waste treatment system as consisting of three treatment trains - one for wastewater, one for secondary sludge, and one for primary or mixed primary and secondary sludge. Figure 1 shows the general layout of such a treatment system. Note how account is taken of the liquid sidestreams generated in the sludge disposal trains that are recycled back to the wastewater treatment train. The dashed lines indicate that the point of mixing between primary and secondary sludges is a decision variable in the program.

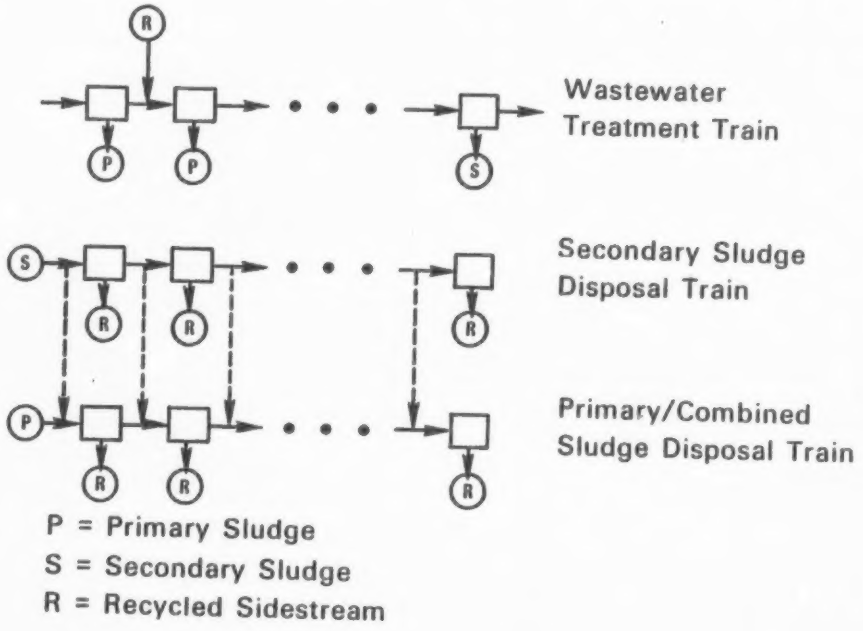

R
P
P
S
Wastewater Treatment Train
S
R
R
R
Secondary Sludge Disposal Train
P
R
R
R
Primary/Combined Sludge Disposal Train
P = Primary Sludge
S = Secondary Sludge
R = Recycled Sidestream

Figure 1. Conceptual flow diagram of a waste treatment system.

Each treatment train consists of a series of treatment stages. For each treatment stage the program user indicates the various unit process options that are available for selection. The user also specifies the quality of the influent wastewater to the system and the required quality of its effluent. EXEC/OP will then select the process option at each stage of the wastewater and sludge treatment trains so that a specified system-wide performance function is approximately optimized. The performance function is a weighted sum of system cost, energy, land use, and subjective undesirability. In addition, the user can constrain the system to meet desired levels on any of these criteria.

This manual provides a set of instructions on how to run the EXEC/OP program. The elements of EXEC/OP and the way in which they are encoded into program input are described. A sample design problem is solved that illustrates the type of program output available. Details regarding the input and output data associated with each unit process sub-model are provided. Finally, descriptions of program subroutines, variable definitions, and the source code listing are included.

This manual and the program contained herein represents a revision of similar material contained in the original report describing EXEC/OP [20]. The latter still remains a valid source for documenting the computational algorithms used in the program.

SECTION 2

ELEMENTS OF EXEC/OP

Multi-Option Flow Diagram

As a preliminary step to using the EXEC/OP computer program the user should prepare a multi-option flow diagram of the system being analyzed. A sample diagram is shown in Figure 2. Its purpose is to display the unit process choices the analyst wishes to consider at each treatment stage of the wastewater and sludge trains. It also indicates to which sludge train the solids produced from wastewater treatment are sent and where the return stream from sludge processing is sent.

The following simple rules must be followed in preparing a multi-option flow diagram:

(1) Treatment stages are numbered in order, starting with those in the wastewater treatment train, followed by those in the secondary sludge train, and then by those in the primary/mixed sludge treatment train.

(2) There must be at least one stage in each of the three treatment trains. If the possibility of separate treatment of primary and secondary sludges is not to be considered then simply use a single stage for the secondary sludge train with the "Null" process as its only treatment option.

(3) The unit process options chosen for consideration at each treatment stage must be taken from Table 1. The "Null" process can be used to represent the option of no treatment. Brief descriptions of each unit process in Table 1, including the design data which must be supplied by the program user, are given in Section 5 of this manual. It is possible to use the same process at different design levels and at several different stages in the system.

(4) The diagram should indicate to which sludge train the sludges from each wastewater treatment stage will be sent. The sidestreams from sludge processing can be assigned to any single wastewater treatment stage except the first stage. As an aid in preparing the sludge treatment portions of the flow diagram, keep in mind the following rule which the program uses to determine where secondary and primary

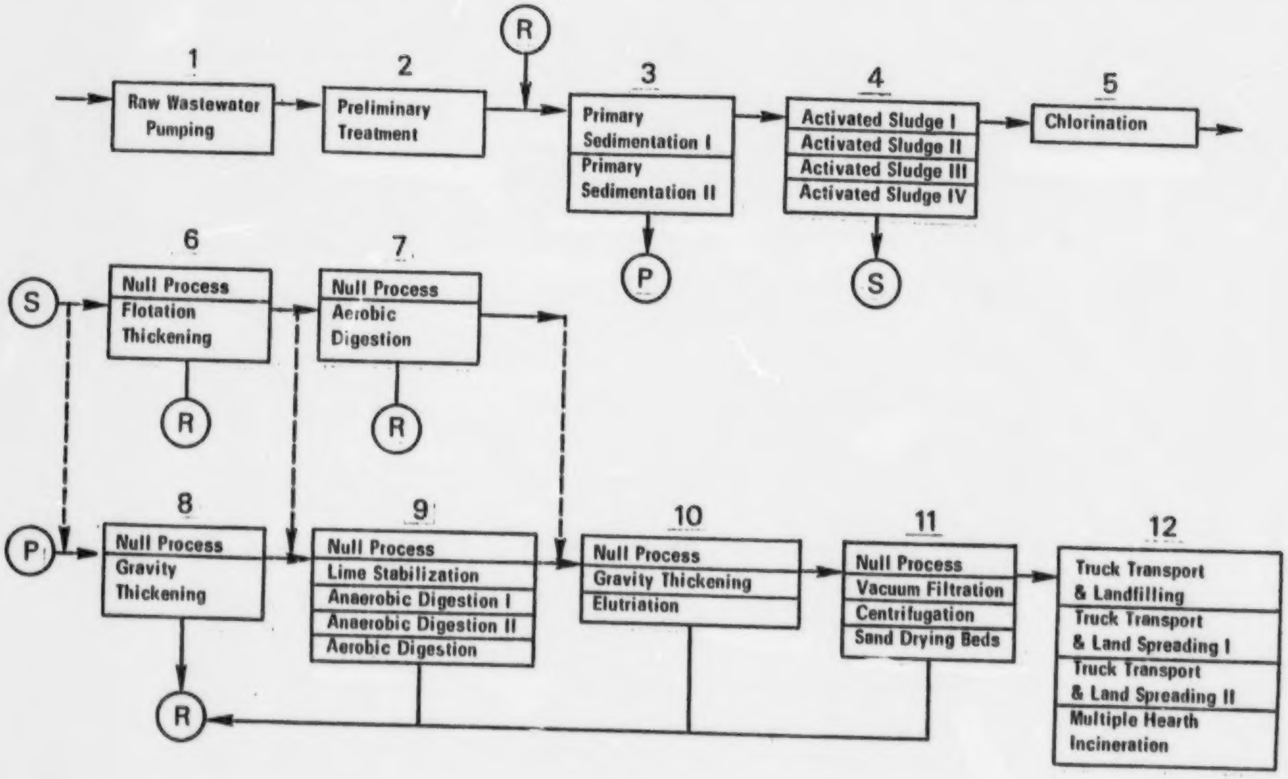

1
Raw Wastewater Pumping
2
Preliminary Treatment
R
3
Primary Sedimentation I
Primary Sedimentation II
P
4
Activated Sludge I
Activated Sludge II
Activated Sludge III
Activated Sludge IV
S
5
Chlorination
S
6
Null Process
Flotation Thickening
R
7
Null Process
Aerobic Digestion
R
P
8
Null Process
Gravity Thickening
R
9
Null Process
Lime Stabilization
Anaerobic Digestion I
Anaerobic Digestion II
Aerobic Digestion
10
Null Process
Gravity Thickening
Elutriation
11
Null Process
Vacuum Filtration
Centrifugation
Sand Drying Beds
12
Truck Transport & Landfilling
Truck Transport & Land Spreading I
Truck Transport & Land Spreading II
Multiple Hearth Incineration

Figure 2. Typical multi-option flow diagram.

TABLE 1. EXEC/OP UNIT PROCESSES

Process	Process ID Number
Null Process	0
Preliminary Treatment	1
Primary Sedimentation	2
Activated Sludge (Aeration Basin and Final Settler)	3
Anaerobic Digestion	6
Vacuum Filtration	7
Gravity Thickening	8
Elutriation	9
Sludge Drying Beds	10
Trickling Filter - Final Settler	11
Chlorination - Dechlorination	12
Flotation Thickening	13
Multiple Hearth Incineration	14
Raw Wastewater Pumping	15
Sludge Holding Tanks	16
Centrifugation	17
Aerobic Digestion	18
Truck Transport/Land Disposal of Sludge (Land Spreading or Landfilling)	22
Lime Stabilization	23
Rotating Biological Contactor - Final Settler	24
Primary Sedimentation - Activated Sludge - Waste Activated Sludge Returned to Primary Clarifier	25
Nonoxidative Heat Treatment	26

sludges are mixed: mixing occurs at the primary sludge stage that is concurrent with the first stage following the end of all secondary sludge processing (e.g., in Figure 2, if secondary sludge treatment ends at stage 6, primary and secondary sludges are mixed prior to stage 9).

Unit Process Sub-Models

For each unit process in Table 1 EXEC/OP contains a process performance sub-model (i.e., a FORTRAN subroutine). These sub-models will compute the resource utilization (e.g., cost, energy, land requirement) of the process as well as the composition of its effluent and side waste streams as a function of the influent waste stream quality and the values of its input design parameters. The input design parameters, fixed in advance by the program user, convey information on such things as required level of treatment, sludge production, kinetic rate coefficients, loading rates, etc. The sub-models also compute values for certain output design parameters such as equipment size, operating capacity, etc. The parameter sets for each process are listed in Section 5 of this manual.

Note that for a given multi-option flow diagram and its associated input design parameter set, an individual system design can be specified by selecting one unit process option at each stage of the system. The total number of alternative individual designs is $n_1 \cdot n_2 \cdot \ldots \cdot n_N$ where n_i is the number of process options at stage i and N is the total number of stages. Although in theory it would be possible to evaluate each alternative system design one by one using the performance sub-models in a similar way as in the EXECUTIVE program [1], EXEC/OP employs a special purpose optimization procedure which greatly reduces the computational burden.

Waste Stream Components.

The multi-option flow diagram in Figure 2 indicates that each treatment stage has an influent waste stream entering it, an effluent stream leaving it, and in most cases, a sidestream generated from the treatment activity. For wastewater treatment stages these sidestreams are sludge streams while for sludge treatment stages they may be filtrates, supernatants, etc. Each waste stream is modeled with the 19 parameters listed in Table 2. In addition to these, each sludge stream is characterized by the

TABLE 2. EXEC/OP WASTE STREAM PARAMETERS

1.	Q	Volumetric Flow, mgd
2.	SOC	Suspended Organic Carbon, mg/l
3.	SNBC	Suspended Nonbiodegradable Organic Carbon, mg/l
4.	SON	Suspended Organic Nitrogen, mg/l
5.	SOP	Suspended Organic Phosphorus, mg/l
6.	SFM	Suspended Fixed Matter, mg/l
7.	SBOD	Suspended 5-Day BOD, mg/l
8.	VSS	Volatile Suspended Solids, mg/l
9.	TSS	Total Suspended Solids, mg/l
10.	DOC	Dissolved Organic Carbon, mg/l
11.	DNBC	Dissolved Nonbiodegradable Organic Carbon, mg/l
12.	DN	Dissolved Nitrogen, mg/l
13.	DP	Dissolved Phosphorus, mg/l
14.	DFM	Dissolved Fixed Matter, mg/l
15.	ALK	Alkalinity, mg/l
16.	DBOD	Dissolved 5-Day BOD, mg/l
17.	NH_3	Ammonia Nitrogen, mg/l
18.	NO_3	Nitrate Nitrogen, mg/l
19.	XASS	Active Biomass Suspended Solids, mg/l

fraction of primary sludge it contains and the type of stabilization it receives (no stabilization, lime stabilization, digestion, digestion plus elutriation, and heat treatment).

The program user must supply values for the first 18 parameters of Table 2 for the system influent wastewater. Maximum allowable effluent limits on 5-day BOD, suspended solids, ammonia nitrogen, nitrate nitrogen, and phosphorus must also be specified.

Design Criteria

EXEC/OP can consider any combination of the criteria listed in Table 3 for selecting optimal designs. The three energy criteria are all expressed in units of equivalent kwh/million gallons of system influent - the program converts all heat and fuel energy into a usable kwh equivalent. Criterion 8, the system undesirability index, is computed in the following manner. Each process option is assigned a subjective undesirability rating by the program user. Any consistent scale, say 0 to 10, can be used where the undesirability increases with increasing rating. The system undesirability index is simply the sum of the individual ratings assigned to those processes that constitute a complete system design.

The eight criteria are used in two ways for defining "optimal" treatment system designs. First, a system objective function is formed as the weighted sum of the individual criteria,

$$V = w_1 c_1 + w_2 c_2 + w_3 c_3 + w_4 c_4 - w_5 c_5 + w_6 c_6 + w_7 c_7 + w_8 c_8$$

where w_i, i=1,... 8 are weighting coefficients whose values are prescribed by the program user and the c_i, i=1,..., 8 are the individual criteria values. EXEC/OP will attempt to select the combination of unit process options that minimize V. Note that w_5 c_5 is given a negative value since energy production is to be maximized. Second, the individual criteria are considered as constraints and each is assigned an upper limit (or lower limit for energy production) which cannot be exceeded by any feasible system design.

Economic Parameters

In order to evaluate the design criteria, the user must supply EXEC/OP with values for the 9 economic and energy conversion parameters listed in Table 4. Item 8, the cost escalator, is a multiplier greater than or equal to 1.0 which is applied to initial construction costs to account for the costs of

TABLE 3. EXEC/OP DESIGN CRITERIA

1. Total Initial Construction Cost (including equipment, materials, piping, and instrumentation), million dollars.
2. Total Annual Operation and Maintenance Cost (including labor, materials, supplies, chemicals and energy), $/million gallons of system influent.
3. Total Equivalent Annual Life Cycle Cost (amortized life cycle construction costs plus annual operation and maintenance costs) $/million gallons of system influent.
4. Total Gross Energy Consumption (direct energy consumed by all equipment and operations) kwh/million gallons of system influent.
5. Total Gross Energy Production (useable energy extracted from treatment by-products such as digester gas and incinerator waste heat), kwh/million gallons of system influent.
6. Total Net Energy Consumption (difference between criteria 4 and 5), kwh/million gallons of system influent.
7. Total Land Area Utilization (only considers those processes with significant land requirements such as drying beds, trickling filters, and land disposal of sludges), acres.
8. System Undesirability Index (see text for explanation).

TABLE 4. EXEC/OP ECONOMIC PARAMETERS

1. Construction Cost Index (3rd quarter 1973 = 1.0)
2. Wholesale Price Index (1967 = 1.0)
3. Discount Rate (as a fraction)
4. Length of Planning Period, years
5. Direct Hourly Wage, $/hr
6. Fraction of Direct Hourly Wage Charged to Indirect Labor Expenses
7. Cost of Electricity, $/kwh
8. Cost Escalator for Engineering, Construction, and Contingencies
9. Heat Energy Conversion Efficiency (as a fraction)

interest, engineering, supervision, and legal fees. Item 9 is an energy conversion efficiency factor. It is used to convert heat energy in BTU's to equivalent available electrical energy in kwh. A typical value would be 0.325 representing 10,500 BTU/kwh.

Design Computations

EXEC/OP is capable of performing two different types of system design computations. The first type approximately identifies the M best designs with objective function values within X% of one another that meet all constraint criteria. M and X are specified by the program user. (A "system design" consists of a choice of a unit process option at each stage of the system). For this type of computation only summary values of the design criteria for each unit process in each system design are available in the program output. The second type of computation allows the user to obtain more detailed information about any single system design. This includes the output design parameters for each unit process and the composition of all waste streams in the system. The design of interest is supplied as part of the program input data.

The user should understand that the optimization procedure used by EXEC-/OP is heuristic in nature and thus there is no guarantee that the true, mathematical optimum design will be found. Experience has shown that in most cases the error will be no more than a few percentage points of the objective function value. Two features have been included in the program to help insure that the optimal design is not missed by very much. The M next-best design feature, with M greater than 1 may be able to identify a better design than that obtained with M=1. Also the problem can be re-run with the user specifying that a particular system design be used to initiate the optimization algorithm rather than have the program default to the standard internal initialization procedure.

Prohibited Process Arrangements

EXEC/OP has internal checks that prohibit choosing process arrangements that will lead to the following situations:

1. pollutant removals less than zero or greater than 1
2. thickening or dewatering a sludge to a lower solids content than its influent value
3. land application of unstabilized sludge
4. landfilling of liquid sludge
5. elutriation of lime stabilized sludge
6. any other loading condition on a process that will result in computing a sizing parameter less than zero.

SECTION 3

INPUT DATA ENCODING

Input data to EXEC/OP is organized according to the card types shown in Figure 3. Table 5 presents a breakdown of the data contained on each card type. Note that one set of Process Design Data Cards is needed for each process option appearing on the multi-option flow diagram. If the same option appears two or more times on the diagram (e.g., the "NULL" process) a separate set of cards is needed for each appearance. Data field 4 of the System Structure card should equal the total number of process options used (i.e., the number of boxes that appears on the multi-option flow diagram).

For the "NULL" process only the first two Process Design Data cards are used. All other unit processes consist of at least 4 cards. Some processes, such as vacuum filtration, centrifugation, and primary sedimentation - activated sludge - waste sludge returned to primary clarifier, require additional supplementary Design Data cards.

The Single Design cards are only used if one wishes to initialize the optimization procedure with a particular system design or if a detailed performance report for a particular system design is desired. Note that for the latter case, the data item in the first field of the Design Selection card must be zero.

All of the data fields listed in Table 5 must be assigned values even if they are not relevant to the design problem at hand. For example, suppose that no effluent limit on phosphorus was required. A value, such as 10000 mg/l, must still appear in the appropriate field of the Effluent Standards card. Also note that even though F10.0 format is used throughout Table 5, a number with a decimal portion, such as 12.345, will be accepted as written.

The following size limits must be observed for any design problem analyzed with EXEC/OP:

a. number of treatment stages ≤ 20

b. number of process options at a single treatment stage ≤ 10

c. total number of unique process options at all stages ≤ 50

d. number of next-best designs ≤ 40

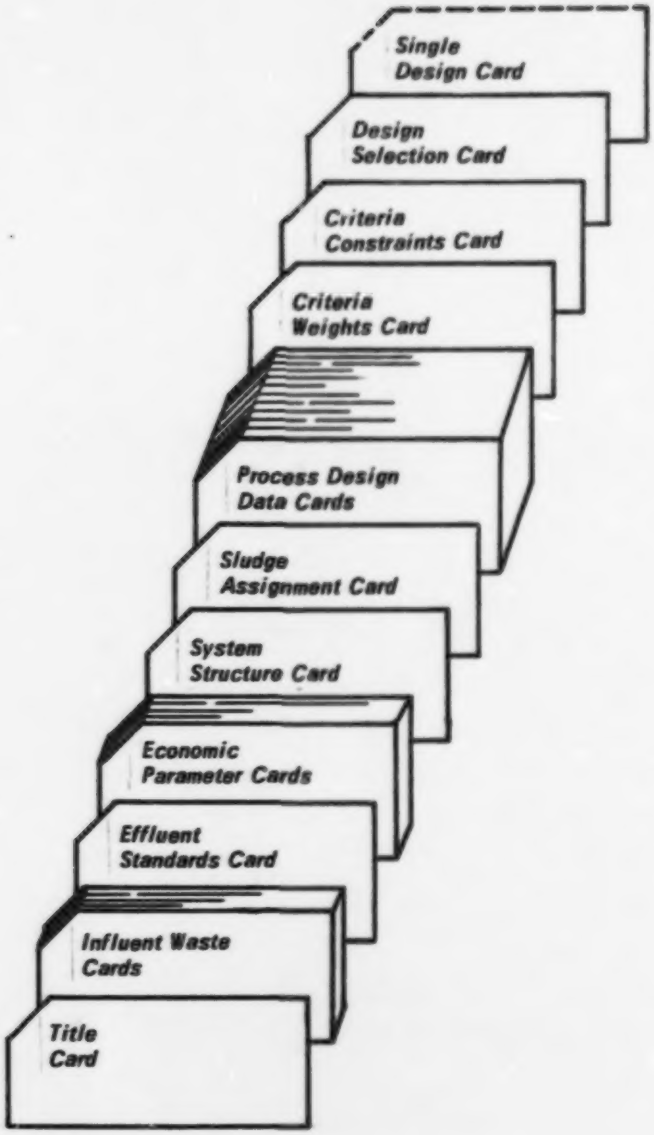

Single Design Card
Design Selection Card
Criteria Constraints Card
Criteria Weights Card
Process Design Data Cards
Sludge Assignment Card
System Structure Card
Economic Parameter Cards
Effluent Standards Card
Influent Waste Cards
Title Card

Figure 3. Organization of input data for EXEC/OP.

TABLE 5. EXEC/OP INPUT DATA

Card Type	Data Field	Description	Format
Title		Descriptive title of design problem	40A2
Influent Waste I	1-8	Influent waste parameters 1-8 of Table 2	8F10.0
Influent Waste II	1-8	Influent waste parameters 9-16 of Table 2	8F10.0
Influent Waste III	1-2	Influent waste parameters 17-18 of Table 2	2F10.0
Effluent Standards	1-5	Required final effluent concentration (mg/l) for 5-day BOD, total suspended solids, ammonia nitrogen, nitrate nitrogen, and phosphorus	5F10.0
Economic Parameters I	1-8	Values of parameters 1-8 of Table 4	8F10.0
Economic Parameters II	1	Value of parameter 9 of Table 4	F10.0
System Structure	1	Number of treatment stages in wastewater train	I10
	2	Number of treatment stages in secondary sludge train	I10
	3	Number of treatment stages in primary sludge train	I10
	4	Total number of process options considered for entire system	I10
	5	Stage number where sidestreams off of sludge processing are returned for treatment	I10
Sludge Assignment	1-n	Treatment stages where sludges produced from wastewater treatment stages 1 to n are sent, where n is the last wastewater treatment stage (sludges can be sent to the first stage of either the primary or secondary sludge trains)	nI10
Process Design Data I	1	Treatment stage number	I10
	2	Option ID number (user assigned and unique to each different unit process or process variation)	I10
	3	Process subroutine ID number from Table 1	I10
	4	Maximum possible energy production from process, kwh/million gallons of system influent	F10.0
	5	Undesirability rating for process	F10.0

(continued)

TABLE 5 (continued)

Card Type	Data Field	Description	Format
Process Design Data II		Descriptive title for the process	40A2
Process Design Data III	1-8	Input design parameters 1-8 (see Section 5 for descriptions)	8F10.0
Process Design Data IV	1-8	Input design parameters 9-16 (see Section 5 for descriptions)	8F10.0
Supplementary Process Design Data	-	See Section 5 for descriptions	8F10.0
		Note: One set of Process Design Data cards is needed for each process option.	
Criteria Weight	1-8	Weighting coefficients for criteria 1-8 of Table 3	8F10.0
Criteria Constraint	1-8	Upper allowable limit (lower limit for energy production) for criteria 1-8 of Table 3	8F10.0
Design Selection	1	Number of best designs to be identified (=0 when a detailed performance report for a particular design is desired).	I10
	2	Maximum fraction by which objective function value of a next-best design can exceed that of the best design.	F10.0
Single Design I Single Design II	1-8 1-8	Option ID number of the process to be chosen at stages 1 to n where n is the last stage of the system. Used only to override the default initialization procedure or when a detailed performance report for a particular design is desired.	8I10

SECTION 4

SAMPLE DESIGN PROBLEM

Problem Design Data

The following hypothetical design problem will be analyzed in order to demonstrate the use of EXEC/OP. A 10 MGD, secondary treatment system for domestic sewage is considered. The multi-option flow diagram chosen for this example is shown in Figure 4. Tables 6 and 7 list values of the major input design parameters used with each process option. The influent waste has 200 mg/l BOD, 250 mg/l suspended solids (76% volatile), and 15 mg/l ammonia nitrogen. Costs are to be indexed to June 1979, the labor wage rate is 8 \$/hr, and a 20 year planning period with a 7% discount rate is to be used. The cost of electricity is taken as 0.04 \$/kwh. The options shown in Figure 4 can be arranged into 2592 alternative system designs.

Sample Design Optimization

EXEC/OP will first be used to identify the five least life cycle cost designs whose net energy consumption is 800 kwh/mil gal or less. Figure 5 lists the card images used for the input data. Numbers have been added in front of each line for ease of referencing - they should not appear in the actual data file submitted to the computer. The DEC PDP-11/70 computer on which this problem was run allows a data field to be terminated by a comma and two successive commas indicates a value of 0. Thus the input data appearing in Figure 5 does not line up in field widths of 10 spaces each.

The following items of interest pertain to the coded input data:

a. Lines 1-3 are the Influent Waste Cards.

b. Line 4 is the Effluent Standards card. Note the large values assigned to effluent ammonia, nitrate, and phosphorus since these parameters are not of interest.

c. Lines 5-6 are the Economic Parameter cards. A construction cost escalator of 1.33 is used and the BTU to kwh conversion efficiency is taken as 0.325.

d. Lines 7-8 are the System Structure and Sludge Assignment Cards, respectively. Note that a total of 25 process options will be used. Also, that sludge from the first three wastewater treatment stages is assigned to the primary sludge train while sludge from the last two stages is assigned to the secondary sludge train.

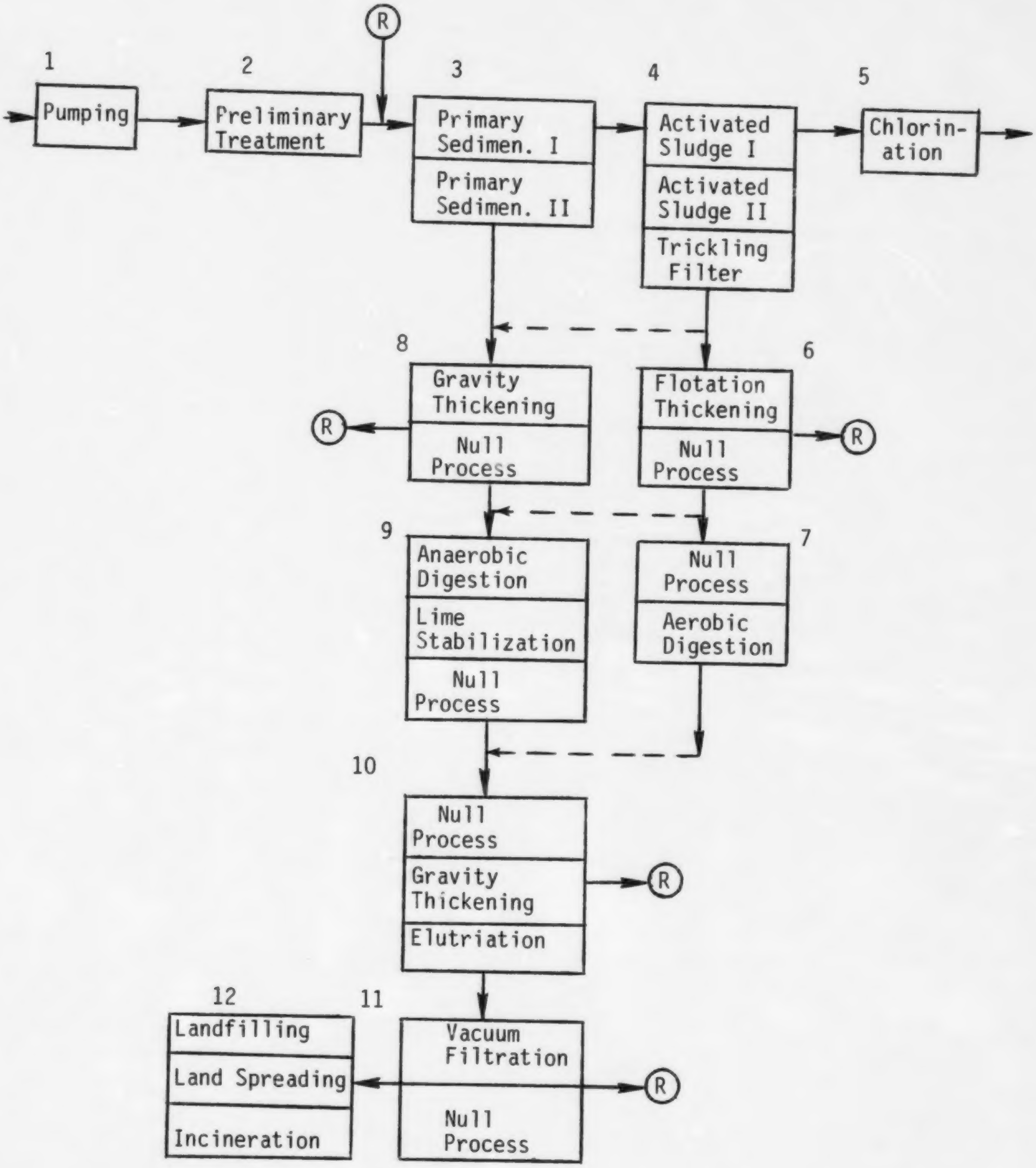

R
1
Pumping
2
Preliminary Treatment
3
Primary Sedimen. I
Primary Sedimen. II
4
Activated Sludge I
Activated Sludge II
Trickling Filter
5
Chlorination
8
Gravity Thickening
Null Process
R
6
Flotation Thickening
Null Process
R
9
Anaerobic Digestion
Lime Stabilization
Null Process
7
Null Process
Aerobic Digestion
10
Null Process
Gravity Thickening
Elutriation
R
12
Landfilling
Land Spreading
Incineration
11
Vacuum Filtration
Null Process
R

Figure 4. Multi-option flow diagram for sample design problem.

TABLE 6. MAJOR PROCESS DESIGN PARAMETERS FOR SAMPLE PROBLEM

PRI = primary sludge SEC = secondary sludge MIX = PRI + SEC

Process	Design Parameter	Value
Pumping	Pumping Head, ft	30.0
Preliminary Treatment	Grit Removal	yes
	Flow Measurement	yes
Primary Sedimentation I	TSS removal, %	50.0
Primary Sedimentation II	TSS removal, %	60.0
Activated Sludge I	MLVSS, mg/l	2500.0
	Recycle ratio	0.3
	Aeration efficiency, %	6.0
Activated Sludge II	MLVSS, mg/l	2500.0
	Recycle ratio	0.3
	Aeration efficiency, lb O_2/hp-hr	1.42
Trickling Filter	Hydraulic loading, mgd/acre	20.0
	Specific Surface Area, sq ft/cu ft	20.0
	Recirculation ratio	3.0
Chlorination	Chlorine dosage, mg/l	8.0
	Contact time, min	30.0
Flotation Thickening	Underflow TSS, %	5.0
	Solids loading, lb/day/sq ft	72.0
Aerobic Digestion	Detention time, days	18.0
Gravity Thickening	Underflow TSS, %	8.0 (PRI) 6.0 (MIX)
	Solids Loading, lb/day/sq ft	25.0 (PRI) 8.0 (MIX)
Anaerobic Digestion	Detention time, days	15.0
	Volatile solids destruction, %	50.0
	Gas production scf/lb VSS	15.0
	Electrical energy recovery efficiency, %	30.0
	Heat energy recovery efficiency,%	20.0
Lime Stabilization	Lime dosage, lb/ton dry solids	400.0

(continued)

TABLE 6 Continued

Process	Design Parameter	Value
Elutriation	Washwater ratio	3.0
	Underflow TSS, %	8.0 (PRI) 5.0 (MIX)
	Solids loading, lb/day/sq ft	20.0 (PRI) 10.0 (MIX)
Vacuum Filtration	See Table 7	
Landfilling	One-way haul distance, mi	5.0
	Cost of land, $/acre	1000.0
Landspreading	One-way haul distance, mi	10.0
	Cost of land, $/acre	1000.0
	Nitrogen limit, lb/ac/yr	600.0
Incineration	Mass loading, lb/hr/sq ft	2.0
	Cost of pollution control, % of total cost	5.0
	Cost of ash disposal, $/ton	5.0

TABLE 7. VACUUM FILTRATION DESIGN PARAMETERS

FOR SAMPLE PROBLEM

Dewatering rate, gph/sq ft - Ferric Chloride dose, lb/ton dry solids - Lime dose, lb/ton dry solids

	Stabilization Process Used			
	Raw	Limed	Digested	Digested & Elutriated
Sludge Type: Primary	17.5-30-140	17.5-30-0	16.25-40-140	16.25-40-0
Primary + Secondary	11.25-60-140	11.25-60-0	10.0-100-250	10.0-100-0

```
                        SAMPLE 10 MGD SYSTEM - 30/30 STDS., JUNE 79 PRICES
   1.              10., 105., 30., 10., 2., 60., 140., 190.
   2.              250., 43., 11., 19., 4., 500., 250., 60.
   3.              15., 0.
   4.              30., 30., 10000., 10000., 10000.
   5.              1.53, 2.335, .07, 20., 8.00, 0., .04, 1.33
   6.              .325
   7.              5, 2, 5, 25, 3
   8.              8, 8, 8, 6, 6
   9.              1, 1, 15, 0., 0.
  10.              RAW WASTEWATER PUMPING (30 FT. HEAD)
  11.              30., , , , , , , ,
  12.              , , , , , , , 1.
  13.              2, 2, 1, 0., 0.
  14.              PRELIMINARY TREATMENT
  15.              1., , , , , , , ,
  16.              , , , , , , , 1.
  17.              3, 3, 2, 0., 0.
  18.              PRIMARY SEDIMENTATION (50% TSS REMOVAL)
  19.              .5, 4., 14., , , , , ,
  20.              , , , , , , 1., 1.
  21.              3, 4, 2, 0., 0.
  22.              PRIMARY SEDIMENTATION (60% TSS REMOVAL)
  23.              .6, 4., 14., , , , , ,
  24.              , , , , , , 1., 1.
  25.              4, 5, 3, 0., 5.
  26.              ACTIVATED SLUDGE ( MLVSS = 2500, 30% RECYCLE,DIFFUSED AERATION)
  27.              30., 30., 2500., .3, 200., .6, 10., .1
  28.              7., .06, 600., 10., 1., 1., 1., 1.
  29.              4, 6, 3, 0., 5.
  30.              ACTIVATED SLUDGE ( MLVSS = 2500, 30% RECYCLE,MECHANICAL AERATION)
  31.              30., 30., 2500., .3, 200., .6, 10., .1
  32.              7., 1.42, 600., 10., 1., 1., 1., 1.
  33.              4, 7, 11, 0., 3.
  34.              TRICKLING FILTER (20 MGD/AC LOADING, RECIRC. RATIO = 3)
  35.              30., 20., 20., 20., 30., 3., 3., 600.
  36.              .5, .5, , , , 1., 1., 1.
  37.              5, 8, 12, 0., 0.
  38.              CHLORINATION (10 MG/L FOR 30 MIN.)
  39.              10., 30., 330., , , , , ,
  40.              , , , , , 1., 1., 1.
  41.              6, 9, 13, 0., 0.
  42.              FLOTATION THICKENING (TO 5% SOLIDS)
  43.              .95, 50000., 1400., 72., 100., 10., 2., 0.
  44.              , , , , , , , 1.
  45.              6, 20, 0, 0., 0.
  46.              NULL PROCESS
  47.              7, 24, 0, 0., 0.
  48.              NULL PROCESS
  49.              7, 10, 18, 0., 2.
  50.              AEROBIC DIGESTION ( FOR 18 DAYS )
  51.              20., 18., .1, .6, 10., .06, , ,
  52.              , , , , , , 1., 1.
  53.              8, 11, 8, 0., 0.
  54.              GRAVITY THICKENING (TO 8, 3, OR 6% SOLIDS DEPENDING ON SLUDGE TYPE)
  55.              .9, 700., 8., 3., 6., 25., 6., 8.
  56.              , , , , , , , 1.
  57.              8, 20, 0, 0., 0.
  58.              NULL PROCESSS
  59.              9,12,6,700.,7.
  60.              ANAEROBIC DIGESTION (FOR 15 DAYS WITH GAS RECOVERY BY IC ENGINE)
  61.              15., 30., .5, 0., 1., .3, .2, 5.71
  62.              .5, 15., , , , , , 1.
  63.              9, 13, 23, 0., 2.
```

Figure 5. Input deck for sample design problem.

```
 64.          LIME STABILIZATION (400 LB/TON LIME DOSAGE)
 65.          400., 45., , , , , , ,
 66.          , , , , , , , 1,
 67.          9, 20, 0, 0., 0.
 68.          NULL PROCESS
 69.          10, 11, 8, 0., 0.
 70.          GRAVITY THICKENING (TO 8, 3, OR 6 % DEPENDING ON SLUDGE TYPE)
 71.          .9, 700., 8., 3., 6., 25., 6., 8.
 72.          , , , , , , , , 1.
 73.          10, 20, 0, 0., 0.
 74.          NULL PROCESS
 75.          10, 14, 9, 0., 0.
 76.          ELUTRIATION (3:1 WASHWATER RATIO)
 77.          .8, 500., 8., 3., 5., 20., 6., 10.
 78.          3., , , , , , , 1.
 79.          11, 15, 7, 0., 5.
 80.          VACUUM FILTRATION (DEWATERING RATE = 10 - 17.5 GPH/SQ FT)
 81.          84., 2000., .064, .0225, 2., 1., , ,
 82.          , , , , , , , , 1.
 83.          17.5, 10., 11.25, 17.5, 10., 11.25, 16.25, 10.
 84.           10., 16.25, 10., 10., 17.5, 10., 11.25
 85.          30., 80., 60., 30., 80., 60., 40., 100.
 86.          100., 40., 100., 100., , , ,
 87.          140., 140., 140., , , , 140., 250.
 88.          250., , , , , , ,
 89.          , , , , , , , , ,
 90.          , , , , , , , ,
 91.          11, 20, 0, 0., 0.
 92.          NULL PROCESS
 93.          12, 16, 22, 0., 5.
 94.          LANDFILLING (5 MILE HAUL)
 95.          2080., 5., 6., .8, 1000., 1., , ,
 96.          , , , , , , 1., 1.
 97.          12, 17, 22, 0., 8.
 98.          LANDSPREADING (10 MILE HAUL, 600 LB/AC/YR N LIMIT)
 99.          2080., 10., 6., .8, 1000., 0., .25, 600.
100.          .03, 500., 10., 500., 10., , 1., 1.
101.          12, 18, 14, 0., 9.
102.          INCINERATION (2 UNITS, 2 LB/HR/SQ FT LOADING)
103.          2., 2., 35., 5., , 10000., 1., .8
104.          , , .05, .05, 5., , , 1.
105.          0., 0., 1., 0., .04, 0., 0., 0.
106.          10000., 10000., 10000., 10000., 0., 800., 10000., 10000.
107.          5, .05
```

Figure 5. (continued)

e. Lines 9-104 contain the Process Design Data Cards. Note that the only process with a non-zero entry for maximum energy production is anaerobic digestion (line 59). Undesirability ratings have been assigned to the options on a scale of 0-10. They are included for illustrative purposes only and are not intended to convey any universal ranking of process types. Lines 83-90 contain the supplementary design data for vacuum filtration as described in Section 5 of this manual.

f. Lines 105 and 106 are the Criteria Weight and Criteria Constraint Cards, respectively. Note that criterion 3, total life cycle cost, is assigned a weight of 1 while criterion 5, energy production is assigned a weight of 0.04. The latter represents the cost credit assigned to electrical energy production since the cost of electricity is being valued at 0.04 $/kwh. Upper constraint levels are all set at very high values with the exception of net energy consumption. It is set at 800 kwh/mil gal as stipulated in the statement of the problem.

g. Line 107, the Design Selection Card, indicates that the 5 best designs within 5% of one another are desired.

Note that since no Single Design Cards are included, the optimization will begin using default values for the penalties attached to generation of return sidestreams from sludge treatment.

The resulting EXEC/OP output for this program is shown in Figure 6. The first four tables summarize the problem process options, the effluent discharge standards, the selection criteria, and the economic parameters, respectively. Following these tables is a listing of the candidate optimal designs arrived at after each new set of penalty terms for recycled sidestreams has been established. Listings of the 5 best designs then follows. Each design listing contains the following information:

a. the objective function value (exact system value),

b. the option ID number (as assigned in the input and listed in the table of process alternatives) of the process used at each stage of the system (the "Null" process choices are not printed),

c. The quantity of sludge either produced or handled by each unit process,

d. values for each of the eight individual design criteria for each unit process and for the entire system,

e. the stage where primary and secondary sludges are mixed together.

```
                              ***************
                              *             *
                              *   EXEC/OP   *
                              *             *
                              * VERSION 1.2 *
                              *             *
                              ***************


                            EXECUTIVE PROGRAM
                          (OPTIMIZATION VERSION)
                                   FOR
             PRELIMINARY SYNTHESIS OF WASTE TREATMENT SYSTEMS


                  U.S. ENVIRONMENTAL PROTECTION AGENCY
                MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
                   SYSTEMS AND ECONOMIC ANALYSIS SECTION
                         CINCINNATI, OHIO 45268



     ****************************************************************************
     *                                                                          *
     *   SAMPLE 10 MGD SYSTEM - 30/30 STDS., JUNE 79 PRICES                     *
     *                                                                          *
     ****************************************************************************



                               PROCESS ALTERNATIVES
                               --------------------


OPTION  PROCESS  STAGE  SIDESTREAM
  NO.     NO.     NO.   DESTINATION                          REMARKS
------  -------  -----  -----------  ------------------------------------------------------------------------------
   1      15       1        8        RAW WASTEWATER PUMPING (30 FT. HEAD)
   2       1       2        8        PRELIMINARY TREATMENT
   3       2       3        8        PRIMARY SEDIMENTATION (50% TSS REMOVAL)
   4       2       3        8        PRIMARY SEDIMENTATION (60% TSS REMOVAL)
   5       3       4        6        ACTIVATED SLUDGE ( MLVSS = 2500, 30% RECYCLE,DIFFUSED AERATION)
   6       3       4        6        ACTIVATED SLUDGE ( MLVSS = 2500, 30% RECYCLE,MECHANICAL AERATION)
   7      11       4        6        TRICKLING FILTER (20 MGD/AC LOADING, RECIRC. RATIO = 3)
   8      12       5        6        CHLORINATION (10 MG/L FOR 30 MIN.)
   9      13       6        3        FLOTATION THICKENING (TO 5% SOLIDS)
  20       0       6        3        NULL PROCESS
  24       0       7        3        NULL PROCESS
  10      18       7        3        AEROBIC DIGESTION ( FOR 18 DAYS )
  11       8       8        3        GRAVITY THICKENING (TO 8, 3, OR 6% SOLIDS DEPENDING ON SLUDGE TYPE)
  20       0       8        3        NULL PROCESSS
  12       6       9        3        ANAEROBIC DIGESTION (FOR 15 DAYS WITH GAS RECOVERY BY IC ENGINE)
  13      23       9        3        LIME STABILIZATION (400 LB/TON LIME DOSAGE)
  20       0       9        3        NULL PROCESS
  11       8      10        3        GRAVITY THICKENING (TO 8, 3, OR 6 % DEPENDING ON SLUDGE TYPE)
  20       0      10        3        NULL PROCESS
  14       9      10        3        ELUTRIATION (3:1 WASHWATER RATIO)
  15       7      11        3        VACUUM FILTRATION (DEWATERING RATE = 10 - 17.5 GPH/SQ FT)
  20       0      11        3        NULL PROCESS
  16      22      12        3        LANDFILLING (5 MILE HAUL)
  17      22      12        3        LANDSPREADING (10 MILE HAUL, 600 LB/AC/YR N LIMIT)
  18      14      12        3        INCINERATION (2 UNITS, 2 LB/HR/SQ FT LOADING)
```

Figure 6. EXEC/OP Output for sample design optimization.

```
                    EFFLUENT DISCHARGE STANDARDS
                    ----------------------------

                  5-DAY BOD, MG/L               30.00
                  SUSPENDED SOLIDS, MG/L        30.00
                  AMMONIA - N, MG/L          10000.00
                  NITRATE - N, MG/L          10000.00
                  PHOSPHORUS, MG/L           10000.00


                       SELECTION CRITERIA
                       ------------------

        CRITERION                             WEIGHT        LIMIT
        ---------                             ------        -----

  1.  INITIAL CONSTR. COST, M$                 0.00      10000.00
  2.  ANNUAL O $ M COST, $/MG                  0.00      10000.00
  3.  TOTAL ANNUAL COST, $/MG                  1.00      10000.00
  4.  ENERGY CONSUMED, KWH/MG                  0.00      10000.00
  5.  ENERGY PRODUCED, KWH/MG                  0.04          0.00
  6.  NET ENERGY CONSUMED, KWH/MG              0.00        800.00
  7.  LAND REQUIRED, ACRES                     0.00      10000.00
  8.  UNDESIREABILITY INDEX                    0.00      10000.00


                         ECONOMIC DATA
                         -------------

             CONSTRUCTION COST INDEX                 1.5300
             WHOLESALE PRICE INDEX                   2.3350
             DIRECT HOURLY WAGE, $/HR                8.0000
             FRACTION CHARGED TO INDIRECT WAGES      0.0000
             COST ESCALATOR FOR MISC. FEES           1.3300
             COST OF ELECTRICITY, $/KWH              0.0400
             BTU TO KWH CONVERSION EFF.              0.3250
             DISCOUNT RATE                           0.0700
             CAPITAL RECOVERY FACTOR                 0.0944


                    CANDIDATE OPTIMAL DESIGNS
                    -------------------------


                          DESIGN   1
                          ----------

                EXACT SYSTEM VALUE         301.289
                APPROX. SYSTEM VALUE       136.075
                PENALTY FROM RECYCLES     -140.220
```

Figure 6. (continued)

```
STAGE  PROCESS   SLUDGE      CONSTR      ANN O&M    TOTAL ANN   ENER USE   ENER PROD   NET ENER   LAND REQD  UNDESIRE-
 NO.   OPTION   TONS/DAY    COST M$    COST $/MG   COST $/MG    KWH/MG     KWH/MG     KWH/MG      ACRES     ABILITY
-----  -------  --------   ---------   ---------   ---------   ---------  ---------  ---------  ---------  ---------
  1       1        0.00      0.8878        9.09       32.05      141.37       0.00     141.37       0.00       0.00
  2       2        0.00      0.2701        8.27       15.26        5.22       0.00       5.22       0.00       0.00
  3       3        6.45      0.4948       10.89       23.69        6.97       0.00       6.97       0.00       0.00
  4       5        4.39      1.6287       38.67       80.79      505.18       0.00     505.18       0.00       5.00
  5       8        0.00      0.2851       19.67       27.04       23.66       0.00      23.66       0.00       0.00
 10      14       10.84      0.1474        1.90        5.71        1.73       0.00       1.73       0.00       0.00
 11      15        8.67      0.5384       29.06       42.99       53.98       0.00      53.98       0.00       5.00
 12      18        9.56      1.5425       33.88       73.77      273.14       0.00     273.14       0.00       9.00
                --------   ---------   ---------   ---------   ---------  ---------  ---------  ---------  ---------
SYSTEM VALUES     10.84        5.79      151.43      301.29     1011.25       0.00    1011.25       0.00      19.00

                  PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8

                  *** DESIGN DOES NOT MEET ALL CONSTRAINT CRITERIA ***


                                DESIGN   2
                                ----------

                     EXACT SYSTEM VALUE              236.916
                     APPROX. SYSTEM VALUE            240.660
                     PENALTY FROM RECYCLES             8.806

STAGE  PROCESS   SLUDGE      CONSTR      ANN O&M    TOTAL ANN   ENER USE   ENER PROD   NET ENER   LAND REQD  UNDESIRE-
 NO.   OPTION   TONS/DAY    COST M$    COST $/MG   COST $/MG    KWH/MG     KWH/MG     KWH/MG      ACRES     ABILITY
-----  -------  --------   ---------   ---------   ---------   ---------  ---------  ---------  ---------  ---------
  1       1        0.00      0.8878        9.09       32.05      141.37       0.00     141.37       0.00       0.00
  2       2        0.00      0.2701        8.27       15.26        5.22       0.00       5.22       0.00       0.00
  3       3        5.62      0.4740       10.35       22.61        6.80       0.00       6.80       0.00       0.00
  4       7        2.73      1.7948       20.86       67.27      172.02       0.00     172.02       0.50       3.00
  5       8        0.00      0.2797       19.06       26.29       22.80       0.00      22.80       0.00       0.00
  8      11        8.35      0.1443        1.86        5.59        1.69       0.00       1.69       0.00       0.00
  9      13        7.52      0.0892       11.50       13.81        3.13       0.00       3.13       0.00       2.00
 12      17        9.03      0.6942       29.40       54.04      107.45       0.00     107.45     428.07       8.00
                --------   ---------   ---------   ---------   ---------  ---------  ---------  ---------  ---------
SYSTEM VALUES      8.35        4.63      110.39      236.92      460.47       0.00     460.47     428.57      13.00

                  PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8


                                DESIGN   3
                                ----------

                     EXACT SYSTEM VALUE              236.916
                     APPROX. SYSTEM VALUE            236.916
                     PENALTY FROM RECYCLES             5.063

                        SAME SYSTEM AS DESIGN   2


                              5 BEST DESIGNS
                              --------------
```

Figure 6. (continued)

```
                                        DESIGN   1
                                        ----------

                              EXACT SYSTEM VALUE         236.916

STAGE  PROCESS   SLUDGE      CONSTR     ANN O&M   TOTAL ANN   ENER USE   ENER PROD   NET ENER   LAND REQD   UNDESIRE-
 NO.   OPTION   TONS/DAY     COST M$    COST $/MG  COST $/MG   KWH/MG     KWH/MG      KWH/MG      ACRES      ABILITY
-----  -------  --------    ---------  ---------  ---------  ---------  ---------   ---------  ---------   ---------
  1       1        0.00       0.0878       9.09      32.05     141.37       0.00      141.37       0.00        0.00
  2       2        0.00       0.2701       8.27      15.26       5.22       0.00        5.22       0.00        0.00
  3       3        5.62       0.4740      10.35      22.61       6.09       0.00        6.09       0.00        0.00
  4       7        2.73       1.7948      20.86      67.27     172.02       0.00      172.02       0.50        3.00
  5       8        0.00       0.2797      19.06      26.29      22.00       0.00       22.00       0.00        0.00
  8      11        8.35       0.1443       1.86       5.59       1.69       0.00        1.69       0.00        0.00
  9      13        7.52       0.0892      11.50      13.81       3.13       0.00        3.13       0.00        2.00
 12      17        9.03       0.6942      29.40      54.04     107.45       0.00      107.45     428.07        8.00
                --------    ---------  ---------  ---------  ---------  ---------   ---------  ---------   ---------
SYSTEM VALUES      8.35         4.63     110.39     236.92     460.47       0.00      460.47     428.57       13.00

                      PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8


                                        DESIGN   2
                                        ----------

                              EXACT SYSTEM VALUE         242.375

STAGE  PROCESS   SLUDGE      CONSTR     ANN O&M   TOTAL ANN   ENER USE   ENER PROD   NET ENER   LAND REQD   UNDESIRE-
 NO.   OPTION   TONS/DAY     COST M$    COST $/MG  COST $/MG   KWH/MG     KWH/MG      KWH/MG      ACRES      ABILITY
-----  -------  --------    ---------  ---------  ---------  ---------  ---------   ---------  ---------   ---------
  1       1        0.00       0.0878       9.09      32.05     141.37       0.00      141.37       0.00        0.00
  2       2        0.00       0.2701       8.27      15.26       5.22       0.00        5.22       0.00        0.00
  3       4        6.78       0.6042      12.24      27.86       8.69       0.00        8.69       0.00        0.00
  4       7        2.15       1.7086      20.21      64.40     156.11       0.00      156.11       0.50        3.00
  5       8        0.00       0.2796      19.05      26.28      22.79       0.00       22.79       0.00        0.00
  8      11        8.94       0.1494       1.92       5.79       1.75       0.00        1.75       0.00        0.00
  9      13        8.04       0.0933      12.05      14.46       3.28       0.00        3.28       0.00        2.00
 12      17        9.66       0.7109      31.18      56.20     114.38       0.00      114.38     446.03        8.00
                --------    ---------  ---------  ---------  ---------  ---------   ---------  ---------   ---------
SYSTEM VALUES      8.94         4.78     114.02     242.38     453.60       0.00      453.60     446.53       13.00

                      PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8


                                        DESIGN   3
                                        ----------

                              EXACT SYSTEM VALUE         237.942

STAGE  PROCESS   SLUDGE      CONSTR     ANN O&M   TOTAL ANN   ENER USE   ENER PROD   NET ENER   LAND REQD   UNDESIRE-
 NO.   OPTION   TONS/DAY     COST M$    COST $/MG  COST $/MG   KWH/MG     KWH/MG      KWH/MG      ACRES      ABILITY
-----  -------  --------    ---------  ---------  ---------  ---------  ---------   ---------  ---------   ---------
  1       1        0.00       0.0878       9.09      32.05     141.37       0.00      141.37       0.00        0.00
  2       2        0.00       0.2701       8.27      15.26       5.22       0.00        5.22       0.00        0.00
  3       3        5.51       0.4724      10.29      22.50       6.80       0.00        6.80       0.00        0.00
  4       7        2.78       1.7986      20.89      67.40     172.64       0.00      172.64       0.50        3.00
  5       8        0.00       0.2798      19.07      26.31      22.82       0.00       22.82       0.00        0.00
  9      12        8.29       1.2358      15.89      47.84     418.54     557.33     -138.79       0.00        7.00
 10      11        6.12       0.1242       1.63       4.84       1.42       0.00        1.42       0.00        0.00
 12      17        5.51       0.6193      21.43      44.04      80.86       0.00       80.86     345.98        8.00
                --------    ---------  ---------  ---------  ---------  ---------   ---------  ---------   ---------
SYSTEM VALUES      8.29         5.69     106.54     260.23     849.68     557.33      292.35     346.48       18.00

                      PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8
```

Figure 6. (continued)

```
                                      DESIGN   4
                                      ----------

                         EXACT SYSTEM VALUE          240.028

STAGE  PROCESS   SLUDGE        CONSTR     ANN O&M   TOTAL ANN   ENER USE   ENER PROD   NET ENER  LAND REQD  UNDESIRE-
 NO.   OPTION   TONS/DAY       COST M$   COST $/MG  COST $/MG    KWH/MG     KWH/MG      KWH/MG     ACRES     ABILITY
-----  -------  --------     ---------  ---------  ---------  ---------  ---------   ---------  ---------  ---------
  1       1        0.00         0.8878       9.09      32.05     141.37       0.00      141.37       0.00       0.00
  2       2        0.00         0.2701       8.27      15.26       5.22       0.00        5.22       0.00       0.00
  3       3        5.95         0.4793      10.53      22.93       6.80       0.00        6.80       0.00       0.00
  4       7        2.97         1.8147      21.01      67.94     175.61       0.00      175.61       0.50       3.00
  5       8        0.00         0.2798      19.07      26.31      22.82       0.00       22.82       0.00       0.00
  8      11        8.92         0.1493       1.92       5.78       1.75       0.00        1.75       0.00       0.00
  9      12        8.03         1.0752      14.56      42.37     291.21     533.89     -242.68       0.00       7.00
 10      11        5.95         0.1226       1.61       4.78       1.40       0.00        1.40       0.00       0.00
 12      17        5.35         0.6351      20.93      43.98      78.82       0.00       78.82     372.29       8.00
                --------     ---------  ---------  ---------  ---------  ---------   ---------  ---------  ---------
SYSTEM VALUES      8.92           5.71     106.99     261.38     725.01     533.89      191.12     372.79      18.00

                         PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8


                                      DESIGN   5
                                      ----------

                         EXACT SYSTEM VALUE          240.935

STAGE  PROCESS   SLUDGE        CONSTR     ANN O&M   TOTAL ANN   ENER USE   ENER PROD   NET ENER  LAND REQD  UNDESIRE-
 NO.   OPTION   TONS/DAY       COST M$   COST $/MG  COST $/MG    KWH/MG     KWH/MG      KWH/MG     ACRES     ABILITY
-----  -------  --------     ---------  ---------  ---------  ---------  ---------   ---------  ---------  ---------
  1       1        0.00         0.8878       9.09      32.05     141.37       0.00      141.37       0.00       0.00
  2       2        0.00         0.2701       8.27      15.26       5.22       0.00        5.22       0.00       0.00
  3       3        5.62         0.4740      10.35      22.61       6.80       0.00        6.80       0.00       0.00
  4       7        2.73         1.7948      20.86      67.27     172.02       0.00      172.02       0.50       3.00
  5       8        0.00         0.2797      19.06      26.29      22.80       0.00       22.80       0.00       0.00
  8      11        8.35         0.1443       1.86       5.59       1.69       0.00        1.69       0.00       0.00
  9      12        7.52         1.0618      14.44      41.90     279.95     513.39     -233.44       0.00       7.00
 12      17        5.51         0.6942      25.86      50.50     107.45       0.00      107.45     428.07       8.00
                --------     ---------  ---------  ---------  ---------  ---------   ---------  ---------  ---------
SYSTEM VALUES      8.35           5.61     109.79     261.47     737.30     513.39      223.90     428.57      18.00

                         PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8

                                BEST DESIGN IS NUMBER   1

                        SEARCH EFFORT WAS   5.2653% OF TOTAL ENUMERATION
```

Figure 6. (continued)

Note that in this problem the first candidate optimal design is infeasible because its energy consumption is greater than 800 kwh/mil gal. The second candidate design appears to be optimal. Inspection of the 5 best designs indicates that it is indeed the best design. By referring back to the Process Alternatives Table one can establish that it consists of raw wastewater pumping, preliminary treatment, primary sedimentation at 50% solids removal, trickling filter, chlorination, and thickening, lime stabilization and land-spreading of combined primary and secondary sludges.

The second best design (Design 3) is only 0.43% more costly. Its value of 237.942 \$/mil gal consists of 260.23 \$/mil gal of life cycle annual cost plus a cost credit of 0.04 \$/kwh x 557.33 kwh/mil gal due to the energy production available from sludge digestion. This design substitutes anaerobic digestion (with energy recovery) and thickening for the thickening - lime stabilization combination of the first best design.

The final line of output indicates that the amount of computational resources used by EXEC/OP for this problem was only about 5.3% of that required to evaluate each of the 2592 possible alternative configurations individually. The processing time for this example was 55.86 seconds on a DEC PDP-11/70 computer.

Sample Single Design Evaluation

In the previous example, the first five best designs all utilized the trickling filter option for BOD removal at stage 4 of the treatment system. To illustrate the single design evaluation feature of EXEC/OP, we can ask what the cost of the system would be if activated sludge had been chosen instead. To do this we will generate a detailed performance report for the following design choices: pumping - preliminary treatment - primary sedimentation (50% solids removal) - activated sludge (mechanical aeration) - chlorination - anaerobic digestion (with energy recovery) - thickening - land spreading of combined sludge. (Anaerobic digestion is used instead of lime stabilization to insure that the energy constraint of 800 kwh/mil gal can be met).

The input data for this example remains the same as in Figure 5 with the following two exceptions:

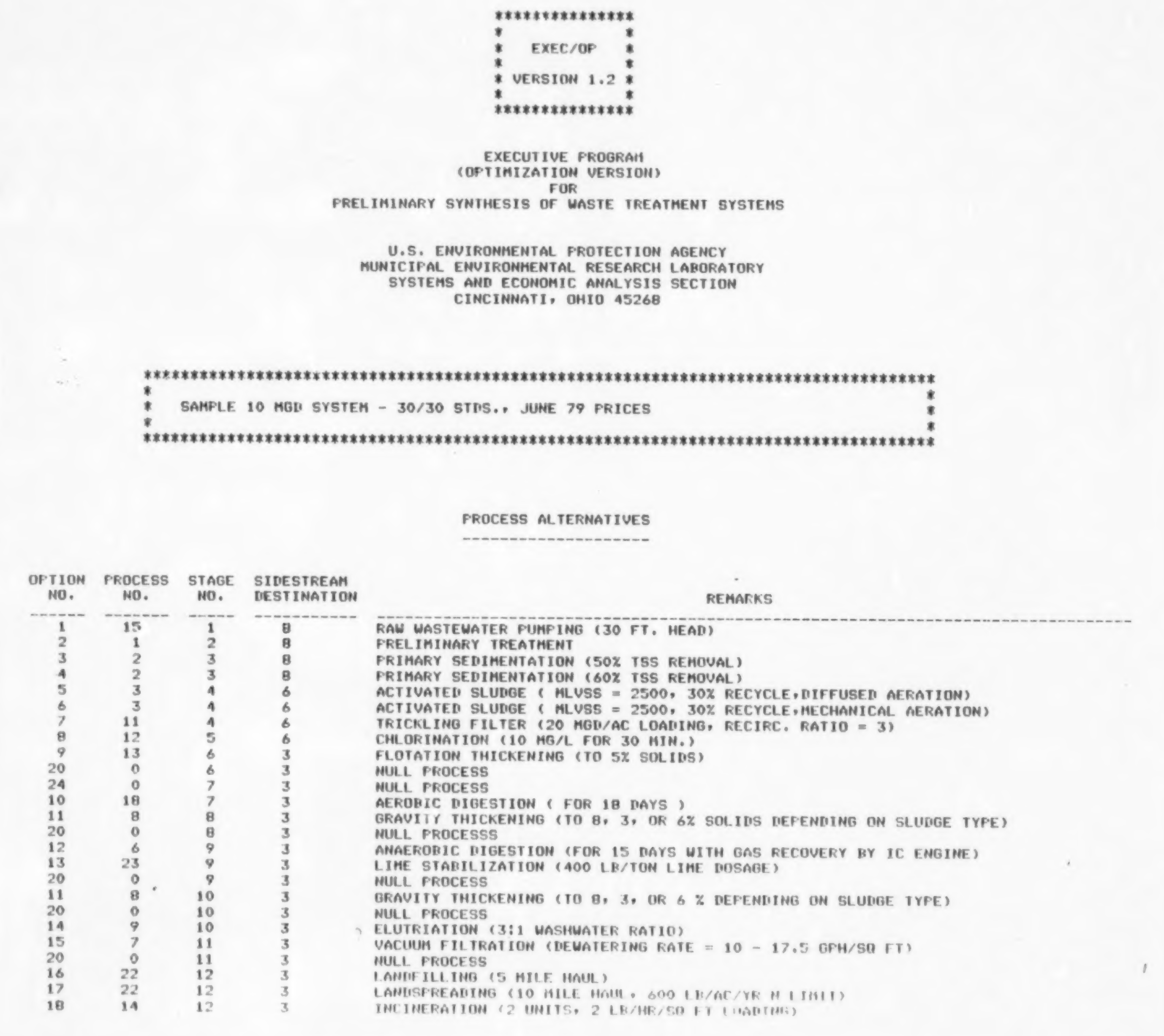
a) the entry in the first data field of line 107 is changed from 5 to 0 thus indicating that a detailed performance report for a single design is desired,

b) lines 108 and 109 are added to the input deck as follows:

1, 2, 3, 6, 8, 20, 24, 20
12, 11, 20, 17

thus specifying the unit process choices for the design of interest.

The EXEC/OP output for this example is given in Figure 7. The first four tables and the design listing are as described earlier. Note that the net cost of this system is 280.26 - (0.04 x 667.72) = 253.55 $/mil gal and is 7% more costly than the least-cost design found in the previous problem. Following the design listing is a summary of the performance characteristics of each treatment stage in the system. It includes the values for all input and output design parameters as well as the composition of the influent, effluent, and side waste streams associated with the stage. Note that the meaning of each design parameter value can be obtained from Section 5 of this manual. For example, with respect to the activated sludge process at stage 4, the value of 1.069 for output design parameter 4 represents the size of the aeration basin in mil gal. Also note that at places where two or more waste streams are mixed together it is the characteristics of the mixed stream that are printed.



```
                              ****************
                              *              *
                              *   EXEC/OP    *
                              *              *
                              * VERSION 1.2  *
                              *              *
                              ****************

                             EXECUTIVE PROGRAM
                          (OPTIMIZATION VERSION)
                                    FOR
                PRELIMINARY SYNTHESIS OF WASTE TREATMENT SYSTEMS

                     U.S. ENVIRONMENTAL PROTECTION AGENCY
                   MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
                     SYSTEMS AND ECONOMIC ANALYSIS SECTION
                          CINCINNATI, OHIO 45268


          ***************************************************************************
          *                                                                         *
          *   SAMPLE 10 MGD SYSTEM - 30/30 STDS., JUNE 79 PRICES                    *
          *                                                                         *
          ***************************************************************************


                              PROCESS ALTERNATIVES
                              --------------------

OPTION  PROCESS  STAGE  SIDESTREAM
  NO.     NO.     NO.   DESTINATION                          REMARKS
------  -------  -----  -----------  --------------------------------------------------------------
   1      15       1         8       RAW WASTEWATER PUMPING (30 FT. HEAD)
   2       1       2         8       PRELIMINARY TREATMENT
   3       2       3         8       PRIMARY SEDIMENTATION (50% TSS REMOVAL)
   4       2       3         8       PRIMARY SEDIMENTATION (60% TSS REMOVAL)
   5       3       4         6       ACTIVATED SLUDGE ( MLVSS = 2500, 30% RECYCLE,DIFFUSED AERATION)
   6       3       4         6       ACTIVATED SLUDGE ( MLVSS = 2500, 30% RECYCLE,MECHANICAL AERATION)
   7      11       4         6       TRICKLING FILTER (20 MGD/AC LOADING, RECIRC. RATIO = 3)
   8      12       5         6       CHLORINATION (10 MG/L FOR 30 MIN.)
   9      13       6         3       FLOTATION THICKENING (TO 5% SOLIDS)
  20       0       6         3       NULL PROCESS
  24       0       7         3       NULL PROCESS
  10      18       7         3       AEROBIC DIGESTION ( FOR 18 DAYS )
  11       8       8         3       GRAVITY THICKENING (TO 8, 3, OR 6% SOLIDS DEPENDING ON SLUDGE TYPE)
  20       0       8         3       NULL PROCESSS
  12       6       9         3       ANAEROBIC DIGESTION (FOR 15 DAYS WITH GAS RECOVERY BY IC ENGINE)
  13      23       9         3       LIME STABILIZATION (400 LB/TON LIME DOSAGE)
  20       0       9         3       NULL PROCESS
  11       8      10         3       GRAVITY THICKENING (TO 8, 3, OR 6 % DEPENDING ON SLUDGE TYPE)
  20       0      10         3       NULL PROCESS
  14       9      10         3       ELUTRIATION (3:1 WASHWATER RATIO)
  15       7      11         3       VACUUM FILTRATION (DEWATERING RATE = 10 - 17.5 GPH/SQ FT)
  20       0      11         3       NULL PROCESS
  16      22      12         3       LANDFILLING (5 MILE HAUL)
  17      22      12         3       LANDSPREADING (10 MILE HAUL, 600 LB/AC/YR N LIMIT)
  18      14      12         3       INCINERATION (2 UNITS, 2 LB/HR/SQ FT LOADING)
```

Figure 7. EXEC/OP output for sample single design evaluation.

```
                 EFFLUENT DISCHARGE STANDARDS
                 ----------------------------

               5-DAY BOD, MG/L              30.00
               SUSPENDED SOLIDS, MG/L       30.00
               AMMONIA - N, MG/L         10000.00
               NITRATE - N, MG/L         10000.00
               PHOSPHORUS, MG/L          10000.00


                       SELECTION CRITERIA
                       ------------------

          CRITERION                        WEIGHT        LIMIT
          ---------                        ------        -----

     1.  INITIAL CONSTR. COST, M$           0.00      10000.00
     2.  ANNUAL O & M COST, $/MG            0.00      10000.00
     3.  TOTAL ANNUAL COST, $/MG            1.00      10000.00
     4.  ENERGY CONSUMED, KWH/MG            0.00      10000.00
     5.  ENERGY PRODUCED, KWH/MG            0.04          0.00
     6.  NET ENERGY CONSUMED, KWH/MG        0.00        800.00
     7.  LAND REQUIRED, ACRES               0.00      10000.00
     8.  UNDESIREABILITY INDEX              0.00      10000.00


                         ECONOMIC DATA
                         -------------

           CONSTRUCTION COST INDEX                  1.5300
           WHOLESALE PRICE INDEX                    2.3350
           DIRECT HOURLY WAGE, $/HR                 8.0000
           FRACTION CHARGED TO INDIRECT WAGES       0.0000
           COST ESCALATOR FOR MISC. FEES            1.3300
           COST OF ELECTRICITY, $/KWH               0.0400
           BTU TO KWH CONVERSION EFF.               0.3250
           DISCOUNT RATE                            0.0700
           CAPITAL RECOVERY FACTOR                  0.0944


STAGE  PROCESS   SLUDGE     CONSTR     ANN O&M  TOTAL ANN  ENER USE  ENER PROD  NET ENER  LAND REQD  UNDESIRE-
 NO.   OPTION   TONS/DAY    COST M$   COST $/MG COST $/MG   KWH/MG    KWH/MG     KWH/MG    ACRES     ABILITY
-----  -------  --------  ---------  --------- ---------  --------- ---------  --------- ---------  ---------
  1       1        0.00     0.8878       9.09     32.05     141.37      0.00     141.37      0.00       0.00
  2       2        0.00     0.2701       8.27     15.26       5.22      0.00       5.22      0.00       0.00
  3       3        5.55     0.4737      10.32     22.57       6.82      0.00       6.82      0.00       0.00
  4       6        3.88     1.3728      37.72     73.22     474.22      0.00     474.22      0.00       5.00
  5       8        0.00     0.2797      19.07     26.30      22.81      0.00      22.81      0.00       0.00
  9      12        9.43     1.5422      18.26     58.14     648.93    667.72     -18.80      0.00       7.00
 10      11        6.83     0.1307       1.70      5.08       1.51      0.00       1.51      0.00       0.00
 12      17        6.14     0.6757      23.49     47.64      89.33      0.00      89.33    420.55       8.00
                --------  ---------  --------- ---------  --------- ---------  --------- ---------  ---------
SYSTEM VALUES      9.43       5.63     127.91    280.26    1390.21    667.72     722.48    420.55      20.00

                     PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE  8
```

Figure 7. (continued)

```
                           PROCESS PERFORMANCE CHARACTERISTICS
                           -----------------------------------

                                   VOLUME FLOW, MGD
                                   CONCENTRATION, MG/L
              CONSULT PROGRAM REFERENCE MANUAL FOR MEANING OF PROCESS INPUT AND OUTPUT DESIGN DATA.


                                 STAGE  1   PROCESS OPTION  1
                                 ----------------------------

                                      INPUT DESIGN DATA:
                    1          2          3          4          5          6          7          8
                 30.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
                    9         10         11         12         13         14         15         16
                  0.000      0.000      0.000      0.000      0.000      0.000      0.000      1.000

                                      OUTPUT DESIGN DATA:
         1          2          3          4          5          6          7          8          9         10
      14.805      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
        11         12         13         14         15         16         17         18         19         20
       0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000

                           INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:
                    Q         SOC        SNBC        SON        SOP        SFM       SBOD        VSS        TSS
 INFLUENT:       10.000    105.000     30.000     10.000      2.000     60.000    140.000    190.000    250.000
 EFFLUENT:       10.000    105.000     30.000     10.000      2.000     60.000    140.000    190.000    250.000
 SIDESTRM:        0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
                   DOC       DNBC         DN         DP        DFM        ALK       DBOD        NH3        NO3
 INFLUENT:       43.000     11.000     19.000      4.000    500.000    250.000     60.000     15.000      0.000
 EFFLUENT:       43.000     11.000     19.000      4.000    500.000    250.000     60.000     15.000      0.000
 SIDESTRM:        0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000


                                 STAGE  2   PROCESS OPTION  2
                                 ----------------------------

                                      INPUT DESIGN DATA:
                    1          2          3          4          5          6          7          8
                  1.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
                    9         10         11         12         13         14         15         16
                  0.000      0.000      0.000      0.000      0.000      0.000      0.000      1.000

                                      OUTPUT DESIGN DATA:
         1          2          3          4          5          6          7          8          9         10
       0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
        11         12         13         14         15         16         17         18         19         20
       0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000

                           INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:
                    Q         SOC        SNBC        SON        SOP        SFM       SBOD        VSS        TSS
 INFLUENT:       10.000    105.000     30.000     10.000      2.000     60.000    140.000    190.000    250.000
 EFFLUENT:       10.073    108.479     33.134     10.730      2.090     67.569    140.766    196.897    264.466
 SIDESTRM:        0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
                   DOC       DNBC         DN         DP        DFM        ALK       DBOD        NH3        NO3
 INFLUENT:       43.000     11.000     19.000      4.000    500.000    250.000     60.000     15.000      0.000
 EFFLUENT:       44.975     11.000     21.890      4.784    500.000    260.375     64.592     17.910      0.000
 SIDESTRM:        0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
```

Figure 7. (continued)

```
                                  STAGE  3   PROCESS OPTION  3
                                  ----------------------------

            NOTE: INFLUENT (EFFLUENT FROM PREVIOUS STAGE) INCLUDES RETURN SIDESTREAMS FROM SLUDGE TREATMENT

                                           INPUT DESIGN DATA:
                     1          2          3          4          5          6          7          8
                 0.500      4.000     14.000      0.000      0.000      0.000      0.000      0.000
                     9         10         11         12         13         14         15         16
                 0.000      0.000      0.000      0.000      0.000      0.000      1.000      1.000

                                           OUTPUT DESIGN DATA:
          1          2          3          4          5          6          7          8          9         10
   1375.249      7.324    277.488      0.000      0.000      0.000      0.000      0.000      0.000      0.000
         11         12         13         14         15         16         17         18         19         20
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000

                            INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:
                     Q        SOC       SNBC        SON        SOP        SFM       SBOD        VSS        TSS
INFLUENT:       10.073    108.479     33.134     10.730      2.090     67.569    140.766    196.897    264.466
EFFLUENT:       10.039     54.419     16.622      5.383      1.048     33.897     70.616     98.775    132.672
SIDESTRM:        0.033  16407.197   5011.492   1622.848    316.092  10219.679  21290.549  29780.320  40000.000
                   DOC       DNBC         DN         DP        DFM        ALK       DBOD        NH3        NO3
INFLUENT:       44.975     11.000     21.890      4.784    500.000    260.375     64.592     17.910      0.000
EFFLUENT:       44.975     11.000     21.890      4.784    500.000    260.375     64.592     17.910      0.000
SIDESTRM:       44.975     11.000     21.890      4.784    500.000    260.375     64.592     17.910      0.000

                                  STAGE  4   PROCESS OPTION  6
                                  ----------------------------

                                           INPUT DESIGN DATA:
                     1          2          3          4          5          6          7          8
                30.000     30.000   2500.000      0.300    200.000      0.600     10.000      0.100
                     9         10         11         12         13         14         15         16
                 7.000      1.420    600.000     10.000      1.000      1.000      1.000      1.000

                                           OUTPUT DESIGN DATA:
          1          2          3          4          5          6          7          8          9         10
     15.569      3.000      2.555      1.069     16.626      0.009   1556.288    943.711    955.354    236.417
         11         12         13         14         15         16         17         18         19         20
    236.417      0.000      3.012      0.000      0.000      0.000      0.000      0.000      0.000      0.000

                            INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:
                     Q        SOC       SNBC        SON        SOP        SFM       SBOD        VSS        TSS
INFLUENT:       10.039     54.419     16.622      5.383      1.048     33.897     70.616     98.775    132.672
EFFLUENT:        9.975      9.890      5.496      2.113      0.338      8.295     10.485     21.705     30.000
SIDESTRM:        0.064   4801.293   2668.007   1025.851    163.996   4026.881   5090.449  10537.662  14564.542
                   DOC       DNBC         DN         DP        DFM        ALK       DBOD        NH3        NO3
INFLUENT:       44.975     11.000     21.890      4.784    500.000    260.375     64.592     17.910      0.000
EFFLUENT:       14.912     11.000     18.638      4.452    500.000    260.375     15.569     18.638      0.000
SIDESTRM:       14.912     11.000     18.638      4.452    500.000    260.375     15.569     18.638      0.000
```

Figure 7. (continued)

```
                                      STAGE  5   PROCESS OPTION  8
                                      ----------------------------

                                          INPUT DESIGN DATA:
                        1           2           3           4           5           6           7           8
                   10.000      30.000     330.000       0.000       0.000       0.000       0.000       0.000
                        9          10          11          12          13          14          15          16
                    0.000       0.000       0.000       0.000       0.000       1.000       1.000       1.000

                                          OUTPUT DESIGN DATA:
            1           2           3           4           5           6           7           8           9          10
    27783.590     151.649       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
           11          12          13          14          15          16          17          18          19          20
        0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000

                             INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:
                        Q         SOC        SNBC         SON         SOP         SFM        SBOD         VSS         TSS
INFLUENT:           9.975       9.890       5.496       2.113       0.338       8.295      10.485      21.705      30.000
EFFLUENT:           9.975       9.890       5.496       2.113       0.338       8.295      10.485      21.705      30.000
SIDESTRM:           0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
                      DOC        DNBC          DN          DP         DFM         ALK        DBOD         NH3         NO3
INFLUENT:          14.912      11.000      18.638       4.452     500.000     260.375      15.569      18.638       0.000
EFFLUENT:          14.912      11.000      18.638       4.452     500.000     260.375      15.569      18.638       0.000
SIDESTRM:           0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000

                                      STAGE  9   PROCESS OPTION 12
                                      ----------------------------

                                          INPUT DESIGN DATA:
                        1           2           3           4           5           6           7           8
                   15.000      30.000       0.500       0.000       1.000       0.300       0.200       5.710
                        9          10          11          12          13          14          15          16
                    0.500      15.000       0.000       0.000       0.000       0.000       0.000       1.000

                                          OUTPUT DESIGN DATA:
            1           2           3           4           5           6           7           8           9          10
        0.500      15.000     195.037   68228.367   35831.855       0.000       0.000       0.000       0.000       0.000
           11          12          13          14          15          16          17          18          19          20
        0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000

                             INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:
                        Q         SOC        SNBC         SON         SOP         SFM        SBOD         VSS         TSS
INFLUENT:           0.097    8774.829    3470.350    1230.246     216.070    6147.121   10636.908   17125.807   23272.928
EFFLUENT:           0.097    4387.415    3470.350     830.416     108.035    8287.847    1838.961    8562.903   16850.750
SIDESTRM:           0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
                      DOC        DNBC          DN          DP         DFM         ALK        DBOD         NH3         NO3
INFLUENT:          25.205      11.000      19.752       4.565     500.000     260.375      32.353      18.389       0.000
EFFLUENT:         316.688      11.000     419.581     112.600     500.000    1687.767     696.231     418.218       0.000
SIDESTRM:           0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
```

Figure 7. (continued)

```
                              STAGE 10   PROCESS OPTION 11
                              ----------------------------

                                  INPUT DESIGN DATA!
                 1           2           3           4           5           6           7           8
             0.900     700.000       8.000       3.000       6.000      25.000       6.000       8.000
                 9          10          11          12          13          14          15          16
             6.000       8.000       0.000       0.000       0.000       0.000       0.000       1.000

                                  OUTPUT DESIGN DATA!
     1           2           3           4           5           6           7           8           9          10
  1706.482       0.000       6.000       8.000       0.000       0.000       0.000       0.000       0.000       0.000
    11          12          13          14          15          16          17          18          19          20
     0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000

                      INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS!
                     Q         SOC        SNBC         SON         SOP         SFM        SBOD         VSS         TSS
INFLUENT!        0.097    4387.415    3470.350     830.416     108.035    8287.847    1838.961    8562.903   16850.750
EFFLUENT!        0.025   15622.146   12356.779    2956.839     384.677   29510.307    6547.937   30489.693   60000.000
SIDESTRM!        0.073     587.151     464.423     111.131      14.458    1109.130     246.101    1145.940    2255.070
                   DOC        DNBC          DN          DP         DFM         ALK        DBOD         NH3         NO3
INFLUENT!      316.688      11.000     419.581     112.600     500.000    1687.767     696.231     418.218       0.000
EFFLUENT!      316.688      11.000     419.581     112.600     500.000    1687.767     696.231     418.218       0.000
SIDESTRM!      316.688      11.000     419.581     112.600     500.000    1687.767     696.231     418.218       0.000


                              STAGE 12   PROCESS OPTION 17
                              ----------------------------

                                  INPUT DESIGN DATA!
                 1           2           3           4           5           6           7           8
          2080.000      10.000       6.000       0.800    1000.000       0.000       0.250     600.000
                 9          10          11          12          13          14          15          16
             0.030     500.000      10.000     500.000      10.000       0.000       1.000       1.000

                                  OUTPUT DESIGN DATA!
     1           2           3           4           5           6           7           8           9          10
   815.714    1631.429       2.000     299.895    2261.003     420.549  420549.125  196284.031       0.189       0.000
    11          12          13          14          15          16          17          18          19          20
     0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000

                      INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS!
                     Q         SOC        SNBC         SON         SOP         SFM        SBOD         VSS         TSS
INFLUENT!        0.025   15622.146   12356.779    2956.839     384.677   29510.307    6547.937   30489.693   60000.000
EFFLUENT!        0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
SIDESTRM!        0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
                   DOC        DNBC          DN          DP         DFM         ALK        DBOD         NH3         NO3
INFLUENT!      316.688      11.000     419.581     112.600     500.000    1687.767     696.231     418.218       0.000
EFFLUENT!        0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
SIDESTRM!        0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000       0.000
```

Figure 7. (continued)

SECTION 5

UNIT PROCESS DESCRIPTIONS

The following pages describe the design parameters associated with each type of unit process currently contained in EXEC/OP. Input design parameters are those which must be supplied as input data to the program. Normally there are 16 such parameters for each process. Of these 16, those not described in these pages are assigned the value of 0. Output parameters are those which are calculated during the execution of EXEC/OP.

The nominal sizes of all equipment are based on providing enough capacity for normal system operation. Actual sizes are computed by multiplying the nominal values by an excess capacity factor. These factors account for any reserve capacity needed to handle peak flows or for periodic cleaning and maintenance. They must be numbers greater than or equal to 1.0 and are specified as part of the input design parameter list for each unit process. Typical values of other input design parameters are shown in parentheses in the listing that follows.

Process ID Number: 1

Process Name: Preliminary Treatment

Description: Consists of grit removal and flow measurement; screening is optional.

Sidestream: None

Input Design Parameters:

1 - screening indicator ; 0 = no screening, 1 = screening (used when raw wastewater pumping is not needed)

16 - excess capacity factor

Output Design Parameters: None

Notes:

1 - Costs are from Ref. 2.

2 - Energy consumption is from Refs. 3 and 4.

ID Number: 2

Process Name: Primary Sedimentation

Description: Removal of suspended solids by gravity settling.

Sidestream: Sludge

Input Design Parameters:

1 - fractional removal of influent suspended solids (.4-.6)

2 - percent solids concentration of sludge underflow (1-4)

3 - hours per week that sludge pumps are operated

15 - excess capacity factor for sludge pumps

16 - excess capacity factor for settling basin

Output Design Parameters:

1 - overflow rate for settler, gpd/sq. ft.

2 - settler surface area, 1000 sq. ft.

3 - sludge pump capacity, gpm

Notes:

1 - overflow rate as function of fractional solids removal is from Ref. 5.

2 - Cost functions are from Ref. 2.

3 - Energy consumption functions are from Refs. 3 and 4.

Process ID Number: 3

Process Name: Activated Sludge - Final Settler

Description: Biological stabilization of organic matter in wastewater by a suspended growth biomass (mixed liquor) fed with oxygen by either diffusers or mechanical aerators in a completely mixed reactor. Mixed liquor solids are separated out in final settler and a portion is recycled back to aeration basin by sludge return pumps.

Sidestream: Sludge

Input Design Parameters:

1 - effluent 5-day BOD limit, mg/l

2 - effluent suspended solids limit, mg/l

3 - mixed liquor volatile suspended solids, mg/l (2000 - 4000)

4 - sludge recycle ratio (.2 - .8)

5 - half-velocity constant, mg/l (20 - 1000)

6 - true yield coefficient, lb biomass/lb BOD (.5 - .7)

7 - maximum substrate removal rate coefficient, 1/day (3 - 20)

8 - biomass decay rate coefficient, 1/day (.1 - .3)

9 - maximum removal rate coefficient for nitrification, 1/day (7)

10 - oxygen transfer efficiency for diffused aeration (.05 - .08) or lb oxygen transferred/hp-hr for mechanical aeration (2 - 5)

11 - overflow rate for final settler, gpd/sq ft (600 - 800)

12 - return sludge pumping head, ft. (10-20)

13 - excess capacity factor for final settler

14 - excess capacity factor for return sludge pumping

15 - excess capacity factor for aeration equipment

16 - excess capacity factor for aeration basin

Output Design Parameters:

1 - influent 5-day BOD, mg/l

2 - sludge age (solids retention time), days

3 - hydraulic retention time, hr

4 - aeration basin volume, mil gal

5 - final settler surface area, 1000 sq ft

6 - fraction of influent suspended solids to settler remaining in effluent

7 - active biomass in mixed liquor, mg/l

8 - refractory volatile suspended solids in mixed liquor, mg/l

9 - inert suspended solids in mixed liquor, mg/l

10 - diffused air requirement, scf/day, or mechanical aerator power requirement, hp

11 - air blower size for diffused aeration, cfm, or mechanical aerator total horsepower

12 - diffused air requirement per gallon of entering wastewater, scf/gal

13 - volume of return sludge stream, mgd

Notes:

1 - BOD removal kinetics, sludge production and air requirements are based on the models of Refs. 6, 7, and 8. The input kinetic rate constants (parameters 5-9) are also taken from these models.

2 - Nitrification is normally assumed to begin after a sludge age of 5 days. If nitrification is not to be allowed, then input design parameter 9 should equal 0.

3 - Cost functions are from Ref. 2.

4 - Energy consumption functions are from Refs. 1 and 4.

Process ID Number: 6

Process Name: Anaerobic Digestion

Process Description: Anaerobic biological stabilization of sludge in a single stage, high rate, completely mixed digester. Gas may be utilized for digester heating or for energy recovery through an IC engine.

Sidestream: None

Input Design Parameters:

1 - detention time, days (15-30)

2 - sludge temperature in digester, degrees C (30-40)

3 - climate correction factor (1.0 for northern U.S., 0.5 for middle U.S., 0.3 for southern U.S.)

4 - program control: 1 = gas utilization for digester heating only; 0 = no direct gas utilization for heating

5 - program control: 1 = energy recovery by using gas to run an IC engine, 0 = no energy recovery

6 - fractional efficiency of electrical energy recovery through IC engine (.30 - .37)

7 - fractional efficiency of heat energy recovery through IC engine (.10 - .33)

8 - cost of auxilary fuel for energy recovery system, $/mil. BTU of heat content

9 - fractional volatile solids destruction (.4 - .7)

10 - gas production, scf/lb volatile solids (14 - 17)

16 - excess capacity factor for digester

Output Design Parameters:

1 - fractional volatile solids destruction

2 - gas production, scf/lb volatile solids

3 - digester volume, 1000 cu ft

4 - methane production, scf/day

5 - carbon dioxide production, scf/day

Notes:

1 - Cost functions for digestion are from Ref. 2.

2 - Cost functions for energy recovery are from Ref. 4.

3 - Energy consumption functions are from Refs. 3 and 4.

Process ID Number: 7

Process Name: Vacuum Filtration

Process Description: Mechanical sludge dewatering on a rotary drum filter subject to an internal vacuum. Includes preliminary chemical conditioning of sludge.

Sidestream: Filtrate

Input Design Parameters:

1 - hours per week of operation

2 - suspended solids concentration in filtrate, mg/l (1500 - 2500)

3 - cost of ferric chloride, $/lb

4 - cost of lime, $/lb

5 - cost of polymer, $/lb

6 - identificaiton number of supplementary input tables (1 - 5)

16 - excess capacity factor

Supplementary Input Design Parameters:

1 - filter dewatering rate, gph/sq ft (8 - 18)

2 - ferric chloride dosage, lb/ton dry solids (0 - 200)

3 - lime dosage, lb/ton dry solids (0 - 400)

4 - polymer dosage, lb/ton dry solids (0 - 40)

Output Design Parameters:

1 - percent moisture of filtered sludge

2 - filter surface area, sq ft

3 - filter cake dry solids production rate, lb/day

4 - actual dewatering rate, gph/sq ft

5 - actual ferric chloride dosage, lb/ton dry solids

6 - actual lime dosgae, lb/ton dry solids

7 - actual polymer dosage, lb/ton dry solids

Notes:

1 - Each supplementary input design parameter consists of 15 values, one for each type of sludge combination shown in the table below. Each set of parameter values is placed onto 2 input data card images in 8F10.0 format in the order shown in the table. Each table is identified by a user-supplied number between 1 and 5 in Input Design Parameter 6.

	Raw	Limed	Digested	Digested & Elutriated	Heat Treated
Primary	1	4	7	10	13
Secondary	2	5	8	11	14
Primary & Secondary	3	6	9	12	15

2 - Prediction of cake moisture and required surface area is from Ref. 9.

3 - Cost functions are from Ref. 2.

4 - Energy consumption functions are from Refs. 3 and 4.

Process ID Number: 8

Process Name: Gravity Thickening

Process Description: Mechanical thickening of sludge by gravity settling and compression.

Sidestream: Supernatant

Input Design Parameters:

1 - solids recovery ratio (.9 - .98)

2 - thickener overflow rate, gpd/sq ft (400 - 800)

3 - underflow thickened solids concentration for primary sludge, % (8 - 10)

4 - underflow thickened solids concentration for secondary sludge, % (2 - 8)

5 - underflow thickened solids concentration for mixed primary and secondary sludge, % (4 - 9)

6 - solids loading rate for primary sludge, lb/day/sq ft (20 - 30)

7 - solids loading rate for secondary sludge, lb/day/sq ft (4 - 18)

8 - solids loading rate for mixed primary and secondary sludge, lb/day/sq ft (8 - 20)

16 - excess capacity factor

Output Design Parameters:

1 - thickener surface area, sq ft

2 - fraction of influent flow going to overflow

3 - actual underflow thickened solids concentration, %

4 - actual solids loading rate, lb/day/sq ft

Notes:

1 - Thickener is sized on the basis of either hydraulic overflow rate or solids loading rate.

2 - Cost functions are from Ref. 2.

3 - Energy consumption functions are from Refs. 3 and 4.

Process ID Number: 9

Process Name: Elutriation

Process Description: Single tank washing and thickening of sludge to reduce consumption of conditioning chemicals.

Sidestream: Supernatant

Input Design Parameters:

1 - solids recovery ratio (.7 - .9)

2 - overflow rate, gpd/sq ft (400 - 600)

3 - underflow solids concentration for primary sludge, % (8 - 10)

4 - underflow solids concentration for secondary sludge, % (2 - 8)

5 - underflow solids concentration for mixed primary and secondary sludge, % (4 - 9)

6 - solids loading rate for primary sludge, lb/day/sq ft (20 - 30)

7 - solids loading rate for secondary sludge, lb/day/sq ft (4 - 18)

8 - solids loading rate for mixed primary and secondary sludge, lb/day/sq ft (8 - 20)

9 - ratio of washwater volume to influent sludge volume (2 - 3)

16 - excess capacity factor

Output Design Parameters:

1 - elutriation tank surface area, sq ft

2 - actual underflow solids concentration, %

3 - actual solids loading rate, lb/day/sq ft

Notes:

1 - Wastewater effluent is used as washwater stream.

2 - Elutriation tank sized on the basis of either hydraulic overflow rate or solids loading rate.

3 - Cost functions are from Ref. 2.

4 - Energy consumption functions are from Refs. 3 and 4.

Process ID Number: 10

Process Name: Sludge Drying Beds

Process Description: Dewatering of stabilized sludge placed on underdrained sand beds by draining and evaporation.

Sidestream: Filtrate

Input Design Parameters:

1 - cost of land, $/acre

2 - suspended solids concentration in underdrain return stream, mg/l (200 - 3000)

3 - percent solids of dried cake for primary sludge (20 - 40)

4 - percent solids of dried cake for secondary sludge (15 - 30)

5 - percent solids of dried cake for mixed primary and secondary sludge (15 - 40)

6 - detention time required for sludge holding tanks, days (5 - 20)

15 - excess capacity factor for sludge holding tanks

16 - excess capacity factor for drying beds

Output Design Parameters:

1 - bed area, sq ft

2 - actual percent solids of dried cake

Notes:

1 - Required bed area is computed as in Ref. 9.

2 - Cost functions are from Ref. 2.

3 - Energy consumption functions are from Ref. 4.

Process ID Number: 11

Process Name: Trickling Filter - Final Settler

Process Description: Biological stabilization of wastewater applied to a rock filter whose media is covered with a biological slime. Includes recirculation of filter effluent. Use of a settler for solids removal is optional.

Sidestream: Sludge

Input Design Parameters:

1 - effluent 5-day BOD limit, mg/l

2 - water temperature, degrees C

3 - filter hydraulic loading (without recirculation), mgd/acre (10 - 40)

4 - specific surface area of filter, sq ft/cu ft (9 - 35)

5 - effluent suspended solids limit, mg/l

6 - percent solids in sludge from clarifier (0 if none used) (1 - 4)

7 - ratio of recirculation flow to filter influent (1 - 4)

8 - clarifier overflow rate, gpd/sq ft (400 - 800)

9 - observed sludge production, lb volatile solids/lb BOD (.4 - .65)

10 - fraction of filter effluent BOD that is settleable (.5)

14 - excess capacity factor for recirculation pumps

15 - excess capacity factor for secondary clarifier

16 - excess capacity factor for trickling filter

Output Design Parameters:

1 - clarifier surface area, 1000 sq ft

2 - filter volume 1000 cu ft

3 - area of filter face, acres

4 - filter depth, ft

Notes:

1 - Filter is sized as in Ref. 10.

2 - Cost functions are from Ref. 2.

3 - Energy consumption functions are from Refs. 1 and 4.

Process ID Number: 12

Process Name: Chlorination - Dechlorination

Process Description: Disinfection of wastewater by chlorine. Dechlorination by sulfur dioxide is optional.

Sidestream: None

1 - dose of chlorine, mg/l (2 - 15)

2 - chlorine contact time, minutes (15 - 30)

3 - cost of chlorine, $/ton

4 - dose of sulfur dioxide, mg/l (2.5)

5 - cost of sulfur dioxide, $/ton

14 - excess capacity factor for the sulfur dioxide feed system

15 - excess capacity factor for the chlorine feed system

16 - excess capacity factor for the contact basin

Output Design Parameters:

1 - volume of the chlorine contact basin, cu ft

2 - amount of chlorine used, tons/yr

3 - amount of sulfur dioxide used, tons/yr

Notes:

1 - Cost functions are from Ref. 2.

2 - Energy consumption functions are from Ref. 4.

Process ID Number: 13

Process Name: Flotation Thickening

Process Description: Thickening of sludges by using bubbles from pressurized air to float solids to surface.

Sidestream: Underflow

Input Design Parameters:

1 - solids recovery ratio (.85 - .95)
2 - suspended solids concentration of thickened sludge, mg/l (40000 - 80000)
3 overflow rate, gpd/sq ft (700 - 1200)
4 - solids loading rate, lb/day/sq ft (10 - 60)
5 - hours per week of operation
6 - dose of conditioning polymer, lb/ton dry solids (2 - 9)
7 - cost of polymer, $/lb
16 - excess capacity factor

Output Design Parameters:

1 - surface area, of each thickener, sq ft
2 - number of standard sized thickeners used
3 - total thickener surface area, sq ft

Notes:

1 - Thickeners are chosen from among a set of commercially available sizes.
2 - Total thickener surface area is computed on the basis of either hydraulic loading or solids loading.
3 - Cost functions are from Ref. 2.
4 - Energy consumption functions are from Ref. 1.

Process ID Number: 14

Process Name: Multiple Hearth Incineration

Process Description: Sludge drying and burning using counter-current passage of heated air and combustion products over continually raked sludge.

Sidestream: None

Input Design Parameters:

1 - mass loading, lb/hr/sq ft of hearth area (2)

2 - number of furnaces (2)

3 - hours per week of operation

4 - number of start-up periods per week

5 - wind velocity, mph

6 - higher heat value of volatiles in sludge, BTU/lb (10000)

7 - type of fuel used ; 1 = fuel oil, 2 = natural gas, 3 = digester gas

8 - cost of fuel oil, $/gal

9 - cost of natural gas, $/1000 cu ft

10 - fractional energy recovery efficiency of exhaust gas (0 - .3)

11 - initial cost of air pollution control equipment, as fraction of incinerator initial construction cost

12 - annual operation and maintenance cost of air pollution control equipment as fraction of incinerator annual O&M cost

13 - ash disposal cost, $/ton

16 - excess capacity factor

Output Design Parameters:

1 - total hearth area, sq ft

2 - total fuel usage, lb/yr

3 - amount of dry solids incinerated, lb/day

4 - cost of electrical power to operate the incinerator, $/yr

5 - cost of fuel to operate the incinerator, $/yr

6 - amount of digester gas burned, cu ft/day

7 - ash production, ton/day

Notes:

1 - Hearth sizing and fuel requirements are computed as in Refs. 9 and 11 on the basis of exit gas temperature of 800 degrees F.

2 - Cost functions are from Ref. 11.

3 - Energy consumption functions are from Ref. 11.

4 - Heat content of exhaust gas is computed as in Ref. 12 assuming ambient temperature of 60 degrees F.

Process ID Number: 15

Process Name: Raw Wastewater Pumping

Process Description: Pumping to provide adequate hydraulic head for gravity flow of wastewater through the subsequent treatment processes.

Sidestream: None

Input Design Parameters:

1 - pumping head, ft (10 - 30)

16 - excess capacity factor

Output Design Parameters:

1 - peak flow pumping capacity, mgd

Notes:

1 - Cost functions are from Ref. 2.

2 - Energy consumption functions are from Ref. 1.

Process ID Number: 16

Process Name: Sludge Holding Tanks

Process Description: Temporary sludge storage.

Sidestream: None

Input Design Parameters:

1 - detention time, days

16 - excess capacity factor

Output Design Parameters:

1 - volume of holding tanks, 1000 cu ft

Notes:

1 - Cost functions are from Ref. 2.

Process ID Number 17

Process Name: Centrifugation

Process Description: Sludge dewatering by inertial solids separation in a rotating bowl.

Sidestream: Centrate

Input Design Parameters:

1 - hours per week of operation

2 - cost of conditioning polymer, \$/lb

3 - identification number of supplementary input table (1 - 5)

16 - excess capacity factor

Supplementary Input Design Parameters:

1 - solids recovery ratio (.5 - .9)

2 - percent solids of centrifuged sludge (5 - 35)

3 - dose of conditioning polymer, lb/ton dry solids (0 - 15)

Output Design Parameters:

1 - design capacity, gpm

2 - dry solids processed, tons/yr

3 - capital recovery and replacement factor for centrifuges based on a 10 year lifetime

4 - actual solids recovery ratio

5 - actual percent solids of centrifuged sludge

6 - actual dose of conditioning polymer

Notes:

1 - Each supplementary input design parameter consists of 15 values, one for each type of sludge combination shown in the table below. Each set of parameter values is placed onto 2 input data card images in 8F10.0 format in the order listed in the table. Each table is identified by a user-suppled number between 1 and 5 in Input Design Parameter 3.

	Raw	Limed	Digested	Digested & Elutriated	Heat Treated
Primary	1	4	7	10	13
Secondary	2	5	8	11	14
Primary & Secondary	3	6	9	12	15

2 - Cost functions are from Ref. 2.

3 - Energy consumption is based on 1 hp/gpm as quoted in Ref. 13.

Process ID Number: 18

Process Name: Aerobic Digestion

Process Description: Aerobic biological stabilization of sludge in a completely mixed continuous flow reactor without recycle.

Sidestream: None

Input Design Parameters:

1 - sludge temperature, degrees C

2 - process detention time, days (12 - 22)

3 - biomass decay rate coefficient, 1/days (.1 - .3)

4 - true yield coefficient, lb biomass/lb 5-day BOD (.5 - .7)

5 - maximum removal rate coefficient for nitrification, 1/days (7)

6 - oxygen transfer efficiency of aeration equipment (.05 - .08)

15 - excess capacity factor for air blowers

16 - excess capacity factor for digester

Output Design Parameters:

1 - digester volume, 1000 cu ft

2 - size of air blower, cfm

Notes:

1 - Volatile solids destruction is modeled as in Ref. 14.

2 - Cost functions are from Ref. 2.

3 - Energy consumption functions are from Ref. 1.

Process ID Number: 22

Process Name: Truck Transport/Land Disposal of Sludge

Process Description: Hauling of either liquid or dewatered sludge by truck to final disposal site; storing liquid sludge at final disposal site; applying either liquid or dewatered sludge to the land or burying dewatered sludge in a landfill.

Sidestream: None

Input Design Parameters:

1 - working hours for hauling per year

2 - one-way hauling distance, miles

3 - depreciation period for trucks, years

4 - fuel cost, $/gal

5 - cost of land, $/acre

6 - type of disposal; 0 = land spreading, 1 = landfilling

7 - storage period for liquid sludge, years (.1 - .5)

8 - maximum allowable nitrogen application rate for land spreading, lb/acre/yr (100 - 1000)

9 - annual land value appreciation rate for spreading sites (as a fraction) (.03)

10 - site preparation cost for spreading liquid sludge, $/acre

11 - application cost for spreading liquid sluge, $/ton dry solids

12 - site preparation cost for spreading dewatered sludge, $/acre

13 - application cost for spreading dewatered sludge, $/ton dry solids

15 - excess capacity factor for trucks

16 - excess capacity factor for sludge storage

Output Design Parameters:

1 - number of trips per year per truck

2 - total number of trips per year

3 - number of trucks

4 - volume of sludge storage, 1000 cu ft

5 - amount of dry solids applied to land, tons/yr

6 - land area required, acres

7 - initial cost of land, $

8 - discounted value of land at end of planning period, $

9 - capital recovery factor, including replacement factor, for trucks

Notes:

1 - Sludge classified as dewatered has a solids content of at least 15%

2 - Costs and energy consumption for truck transport are from Ref. 15.

3 - Costs for landfills are from Ref. 16.

4 - Costs of storage lagoons are from Ref. 2.

5 - Energy consumption functions for land spreading and landfilling are from Ref. 4.

Process ID Number: 23

Process Name: Lime Stabilization

Process Description: Chemical stabilization of sludges by adding lime to raise the pH to 11 - 11.5.

Sidestream: None

Input Design Parameters:

1 - lime dosage, lb/ton dry solids (200 - 500)

2 - cost of lime, $/ton

16 - excess capacity factor

Output Design Parameters:

1 - lime addition rate, lb/day

2 - amount of sludge treated, tons of dry solids/day

Notes:

1 - Cost functions are from Ref. 2.

2 - Energy consumption functions are from Ref. 4.

Process ID Number: 24

Process Name: Rotating Biological Contactor - Final Settler

Process Description: Biological stabilization of organic matter in wastewater by a biological slime attached to a mechanically driven disk which is turned through the wastewater. Several disks can be used in series. Biological solids that slough off the disks are settled out in a clarifier.

Sidestream: Sludge

Input Design Parameters:

1 - effluent 5-day BOD limit, mg/l
2 - number of stages in series (4)
3 - water temperature, degrees C
4 - BOD removal rate constant at 20 degrees C, gpd/sq ft (1 - 7)
5 - nitrification rate constant at 20 degrees C, gpd/sq ft (.5 - 4)
6 - overflow rate for final settler, gpd/sq ft (600 - 800)
7 - concentration of BOD at which nitrification begins, mg/l (20)
8 - percent solids concentration of sludge from final settler underflow (1 - 4)
9 - cost of installed concrete, $/cu yd
10 - observed sludge production, lb volatile solids/lb BOD (.4 - .6)
15 - excess capacity factor for final settler
16 - excess capacity factor for contactor

Output Design Parameters:

1 - temperature adjusted BOD removal rate constant, gpd/sq ft
2 - temperature adjusted nitrification rate constant, gpd/sq ft
3 - area per contactor stage, sq ft
4 - total active contactor area, sq ft
5 - number of stages required to achieve the BOD concentration at which nitrification begins
6 - number of remaining stages for nitrification
7 - fraction of influent BOD remaining in effluent
8 - percent ammonia nitrogen removal
9 - overall hydraulic loading, gpd/sq ft
10 - surface area of final settler, sq ft
11 - sludge production, lb dry solids/day
12 - fraction of suspended solids remaining after settling

13 - number of 100,000 sq ft shafts per stage
14 - total number of 100,000 sq ft shafts
15 - materials and supplies cost, \$/yr
16 - electrical power cost, \$/yr
17 - labor cost, \$/yr

Notes:

1 - Waste stream transformation and sludge production is modeled as in Ref. 1.

2 - Cost functions are from Ref. 1.

3 - Energy consumption is based on 5 hp per shaft.

Process ID Number: 25

Process Name: Primary Sedimentation - Activated Sludge

Process Description: Consists of primary sedimentation unit (Process ID No. 2) and activated sludge - final settler unit (Process ID No. 3) where waste activated sludge is recycled back to the primary settler.

Sidestream: Sludge

Input Design Parameters:

1 - option number assigned to primary sedimentation unit

2 - option number assigned to activated sludge - final settler unit

Supplementary Input Design Parameters:

1 through 16 - same as those for Primary Sedimentation (Process ID No. 2)

17 through 32 - same as those for Activated Sludge - Final Settler (Process ID No. 3)

Output Design Parameters:

1 - primary settler overflow rate, gpd/sq ft

2 - primary settler surface area, 1000 sq ft

3 - fraction of sludge produced by primary sedimentation

4 - sludge age (solids retention time), days

5 - final settler surface area, 1000 sq ft

6 - aeration basin volume, mil gal

7 - diffused air requirement, scf/day, or mechanical aerator power requirement, hp

8 - blower size, cfm or mechanical aerator total horsepower

Notes:

1 - See notes for Primary Sedimentation and Activated Sludge - Final Settler processes.

Process ID Number: 26

Process Name: Nonoxidative Heat Treatment

Process Description: Thermal conditioning of sludge by heating under pressure in the absence of oxygen resulting in volatile solids solubilization, pasteurization, and improved dewatering characteristics.

Sidestream: None

Input Design Parameters:

1 - operating temperature, degrees C (150 - 220)
2 - hours per week of operation
3 - number of start-up periods per week
4 - fuel cost, $/mil BTU of heat content
5 - detention time for sludge holding tanks, days
15 - excess capacity factor for sludge holding tanks
16 - excess capacity factor for heat treatment reactor

Output Design Parameters:

1 - capacity of the heat treatment unit, gpm
2 - fraction of influent suspended COD remaining in effluent
3 - fraction of influent volatile solids remaining in effluent
4 - annual heat requirement, mil BTU/yr

Notes:

1 - Solubilization of suspended BOD and volatile solids is based on operating temperature as described in Ref. 17.

2 - Cost functions are from Ref. 18.

3 - Energy consumption functions are from Ref. 19.

SECTION 6

PROGRAM LISTING

List of Subroutines

EXEC/OP consists of a MAIN program, 10 subroutines that perform input, output, and various functions associated with the optimization algorithm, plus 21 additional subroutines that model each unit process. For each subroutine, Table 8 lists the subroutines that call it, the parameters passed to and returned from it, and a brief description of its purpose. Definitions of the parameters can be found in the next sub-section.

Depending on the type of computer used, the entire EXEC/OP program may not be able to fit in active core at one time. Should a program overlay be necessary, Figure 8 diagrams the appropriate overlay structure to be used.

TABLE 8. EXEC/OP SUBROUTINES

Name	Called By	Passed Parameters[1]	Returned Parameters[1]	Purpose
MAIN				Main program of EXEC/OP
INPUT	MAIN		ISW	Reads in problem design data
OUTPUT	MAIN			Prints out system design evaluation
OPTIM	MAIN	NPHASE LIMIT FACTOR	WVP PV IFEAS	Uses an implicit enumeration algorithm to identify the first M (= LIMIT) best designs with respect to a penalty augmented weighted objective function
SAVE	OPTIM	KOUNT WVPK LIMIT		Inserts a next-best design into a list
SIMUL	MAIN		WV V NITER	Computes actual performance of a given system configuraton by means of a simple iterative scheme on the contents of returned sidestreams from sludge treatment
PNALTY	MAIN	V1		Estimates the penalty (increase) in each criterion due to returning a unit quantity of each sludge treatment sidestream component
SYSTEM	SIMUL PNALTY	RECYC	WV V	Evaluates performance of a given system design configuration for a given quality of return flow from sludge treatment
UNIT	OPTIM SYSTEM	J IPROC		Computes performance of unit process type IPROC at stage J of system

(continued)

TABLE 8 CONTINUED

Name	Called By	Passed Parameters[1]	Returned Parameters[1]	Purpose
STRMIN	OPTIM SYSTEM	J RECYC		Determines the type of waste streams entering stage J
SMIX	STRMIN SIMUL PNALTY	J J1 J2 J3		Mixes together all waste streams J1 through J2 whose destination is stage J3 and puts results in stream J
PREL	UNIT			Evaluates preliminary treatment unit process
PRSET	UNIT PSAS			Evaluates primary sedimentation unit process
AERFS	UNIT PSAS			Evaluates activated sludge unit process
DIG	UNIT			Evaluates anaerobic digestion unit process
VACF	UNIT			Evaluates vacuum filtration unit process
THICK	UNIT			Evaluates gravity thickening unit process
ELUT	UNIT			Evaluates elutriation unit process
SBEDS	UNIT			Evaluates sludge drying beds unit process
TRFS	UNIT			Evaluates trickling filter unit process
CHLOR	UNIT			Evaluates chlorination unit process
TFLOT	UNIT			Evaluates flotation thickening unit process
MHINC	UNIT			Evaluates multiple hearth incineration unit process

(continued)

TABLE 8. CONTINUED

Name	Called By	Passed Parameters[1]	Returned Parameters[1]	Purpose
RWP	UNIT			Evaluates raw wastewater pumping unit process
SHT	UNIT			Evaluates sludge holding tank unit process
CENT	UNIT			Evaluates centrifugation unit process
AEROB	UNIT			Evaluates aerobic digestion unit process
LANDD	UNIT			Evaluates truck transport - land disposal unit process
LIME	UNIT			Evaluates lime stabilization unit process
RBC	UNIT			Evaluates rotating biological contactor unit process
PSAS	UNIT			Evaluates combined primary sedimentation activated sludge unit process where waste activated sludge is returned to the primary settler
HEAT	UNIT			Evaluates non-oxidative heat treatment unit process

---

[1] Exclusive of those in COMMON; see next sub-section for definition of variables.

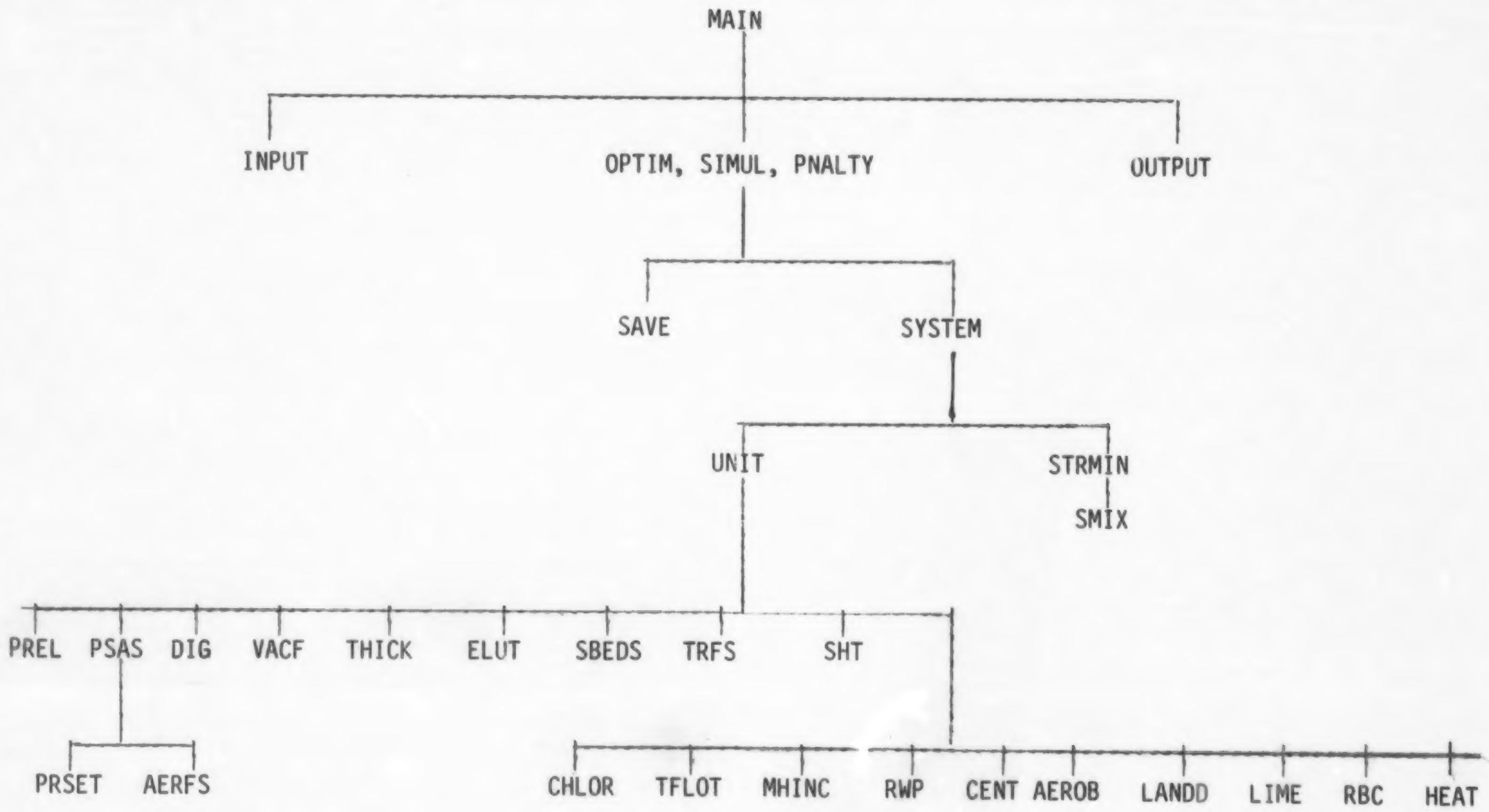

MAIN
INPUT
OPTIM, SIMUL, PNALTY
OUTPUT
SAVE
SYSTEM
UNIT
STRMIN
SMIX
PREL
PSAS
DIG
VACF
THICK
ELUT
SBEDS
TRFS
SHT
PRSET
AERFS
CHLOR
TFLOT
MHINC
RWP
CENT
AEROB
LANDD
LIME
RBC
HEAT

Figure 8. Overlay structure of EXEC/OP.

Definitions of Program Variables

(Footnotes appear at the end of this sub-section)

ACOST(I)	annual amortized capital cost of item I, ¢/1000 gal
AF	amortization (capital recovery) factor
ALAND	land area, acres
B(K)	constraint level placed on criterion K[1]
C(J,K)	value of criterion K at treatment stage J[1]
CCI	construction cost index
CCOST(I)	construction cost of cost item I, $
CENT4(I,J,L)	solids recovery ratio for centrifuge L and sludge type (I,J)[2]
CENT5(I,J,L)	percent solids of centrifuged sludge for centrifuge L and sludge type (I,J)[2]
CENT6(I,J,L)	dose of conditioning polymer, lb/ton dry solids, used for centrifuge L and sludge type (I,J)[2]
CF	conversion efficiency factor for converting heat energy to equivalent electrical energy
CKWH	cost of electricity, $/kwh
COSTO(I)	annual operation and maintenance cost of cost item I, ¢/1000 gal
CP(K)	value of penalty for criterion K due to having to treat return flows from sludge treatment
C5JMAX(J)	maximum possible energy production possible at treatment stage J, kwh/mil gal
C5MAX	maximum possible energy production possible from the system, kwh/mil gal
DHR	direct hourly wage, $/hr
DMATX(I,N)	input design parameter I for process N (see Section 5 for descriptions of parameters for each type of process)

DV(I,K)	change in value of criterion K after component I of sludge treatment sidestreams has been recycled[1]
DVSUM(K)	sum of changes in criterion K after all components of sludge treatment sidestreams have been individually recycled[1]
EEP	equivalent electrical energy production, kwh/day
EER	equivalent electrical energy required, kwh/day
EFFSTD(I)	effluent discharge standard for waste component I
	I=1: 5-day BOD, mg/l
	I=2: suspended solids, mg/l
	I=3: ammonia nitrogen, mg/l
	I=4: nitrate nitrogen, mg/l
	I=5: phosphorus, mg/l
	I=6-20: not used
EMAX	maximum possible energy production possible from a given unit process option kwh/mil gal
FACTOR FACTR	multiplier on weighted objective function used to limit values of next-best designs
FEM	approximate number of unit process performance evaluations needed if total enumeration of all system configurations were made
FPS(J)	fraction of primary sludge contained in sludge stream J
IAERF	error indicator for unit process subroutines (=1 means design assumptions cannot be met)
IFEAS	feasibility indicator; 0 = infeasible design, 1 = feasible design
INP	input unit device number (may depend on computer system)
IO	output unit device number (may depend on computer system)
IP(J)	process (subroutine) ID no. of option J
IPROC	process (subroutine) ID no.

ISC(J)	sludge stabilization code associated with stream J; 1 = raw 2 = lime stabilized 3 = digested 4 = digested and elutriated 5 = heat treated
ISW	0 = default values for recycle penalties are used, 1 = penalties based on an initial system design stipulated by user
IS1	ID no. of primary influent stream to a process
IS2	ID no. of secondary influent stream to a process
IZBAR(J)	temporary value of option ID no. for optimal process choice at stage J
IZOPT(J)	option ID no. of optimal process choice at stage J
IZSAVE(L,J)	option ID no. of process choice at stage J for next-best design L
JRECYC	treatment stage where sidestreams from sludge processing are returned to
JSIDE(J)	stage where sludge stream from stage J is sent for processing
JSTRM(L)	L = 1: stream no. of system influent L = 2: stream no. of influent to last wastewater treatment stage L = 3: stream no. of influent to first secondary sludge treatment stage L = 4: stream no. of influent to last secondary sludge treatment stage L = 5: stream no. of influent to first primary sludge treatment stage L = 6: stream no. of influent to last primary sludge treatment stage L = 7: stream no. of sludge from first wastewater treatment stage

L = 8:
L = 9: not used

L = 10: stream no. of sludge from last wastewater treatment stage

L = 11: stream no. of sidestream from first secondary sludge treatment stage

L = 12: stream no. of sidestream from last secondary sludge treatment stage

L = 13: stream no. of sidestream from first primary sludge treatment stage

L = 14: stream no. of sidestream from last primary sludge treatment stage

L = 15: stream no. of effluent from wastewater treatment train

L = 16: stream no. of effluent from secondary sludge treatment train

L = 17: stream no. of effluent from primary sludge treatment train

L = 18:
L = 19: not used

L = 20: see JRECYC

L = 21: stage where secondary sludge is mixed with primary sludge

L = 22: option ID no. assigned to the Null Process

KMAX	number of next-best designs desired
KOUNT	number of next-best designs currently identified
KPROC(L,J)	option ID no. of the Lth process option at stage J
LIMIT	see KMAX
LSAVE(J)	pointer to last process option evaluated at stage J during the optimization algorithm
MITER	iteration counter on number of sets of recycle penalties used during optimization algorithm
MITMAX	maximum number of sets of recycle penalties allowed
MITMIN	iteration or next-best design which contains the optimal design

N	option ID no. of a unit process option
NITER	number of iterations needed to evaluate the performance of a system design with recycled sidestreams properly accounted for
NITMAX	maximum allowable value of NITER
NITSUM	accumulated value of NITER over all system design evaluations
NPHASE	1 = design optimization phase, 2 = next-best design phase of program
NPROC(J)	number of process options contained at treatment stage J
NPSPS	number of primary sludge processing stages
NSSPS	number of secondary sludge processing stages
NTPS	total number of treatment stages in system
NTPU	total number of unit process options in system
NWPS	number of wastewater treatment stages
OMATX(I,N)	output design parameter I for process N (see Section 5 for descriptions of parameters for each type of process)
OS1	ID no. of effluent stream from a process
OS2	ID no. of sludge or sidestream generated by a process
P(I,K)	recycle penalty (increase in criterion K) by generating a unit of waste stream component I in the sidestream of a given sludge treatment process[1,3]
PCT	fraction of direct hourly wage charged to indirect labor costs
PINFLO(I)	concentration (or volumetric flow) of component I of system influent wastewater[3]
PJ(J,K)	optimal total value of recycle penalty for criterion K up through the first J treatment stages[1]
PSAVE(I,K)	recycle penalty for waste stream component I and criterion K used to identify the optimal system design[1,3]
PV	total penalty assessed to system design due to the impact of recycled streams from sludge treatment

RATIO	multiplier used to increase construction costs to account for engineering, supervision, legal fees, interest
RECYC(I)	value of waste stream component I_3in recycled sidestreams from sludge treatment^3
RI	discount rate
SEFF	search efficiency, or total computational effort as a percent of that required using complete enumeration of all system configurations
SMATX(I,J)	value of waste stream component I in stream J; I = 1: not used I = 2: volumetric flow, mgd I = 3: suspended organic carbon, mg/l I = 4: suspended nonbiodegradable carbon, mg/l I = 5: suspended organic nitrogen, mg/l I = 6: suspended organic phosphorus, mg/l I = 7: suspended fixed matter, mg/l I = 8: suspended 5-day BOD, mg/l I = 9: volatile suspended solids, mg/l I = 10: total suspended solids, mg/l I = 11: soluble organic carbon, mg/l I = 12: soluble nonbiodegradable carbon, mg/l I = 13: soluble nitrogen, mg/l I = 14: soluble phosphorus, mg/l I = 15: soluble fixed matter, mg/l I = 16: alkalinity, mg/l I = 17: soluble 5-day BOD, mg/l I = 18: ammonia nitrogen, mg/l I = 19: nitrate nitrogen, mg/l I = 20: suspended active biomass, mg/l

STOT	total sludge production, tons/day
S2	sludge produced or handled by a given unit process, tons/day
TITLE	descriptive title given to design problem and each unit process option
TRECYC(I)	temporary value of component I in recycled sidestreams from sludge treatment[3]
TSE	number of times system designs are evaluated with recycled sidestreams from sludge treatment properly accounted for
TUPE	total number of times that unit process performances are evaluated
UDR(N)	undesirability rating for process option N
V(K)	system-wide value of selection criterion K;
	K = 1: initial construction cost, mil $
	K = 2: annual operation and maintenance cost, $/mil gal
	K = 3: equivalent annual total life cycle cost, $/mil gal
	K = 4: gross energy consumption, kwh/mil gal
	K = 5: energy production, kwh/mil gal
	K = 6: net energy consumption, kwh/mil gal
	K = 7: land requirement, acres
	K = 8: undesirability rating
	K = 9: K = 10: not used
VACF7(I,J,L)	dewatering rate, gph/sq ft, for vacuum filter L and sludge type (I,J)[2]
VACF8(I,J,L)	ferric chloride dosage, lb/ton dry solids, for vacuum filter L and sludge type (I,J)[2]
VACF9(I,J,L)	lime dosage, lb/ton dry solids, for vacuum filter L and sludge type (I,J)[2]
VACF10(I,J,L)	polymer dosage, lb/ton dry solids, for vacuum filter L and sludge type (I,J)[2]

VJ(J,K)	optimal value of criterion K up through first J treatment stages[1]
VR1(K)	value of criterion K in optimal system after a single component of the return stream from sludge treatment has been recycled[1]
VSAVE(M)	objective function value of M-th next-best design
VO(K)	value of criterion K in optimal design when effect of recycled sidestreams from sludge treatment is ignored[1]
V1(K)	value of criterion K in optimal design when all recycled sidestreams from sludge treatment have been properly accounted for[1]
W(K)	objective function weight assigned to criterion K[1]
WPI	Wholesale Price Index
WV	weighted objective function value
WVP	weighted objective function value plus penalty terms
WVPBAR	current optimal value of WVP
WVPK	temporary value of WVP
WVSAVE(L)	value of WVP obtained for the Lth set of recycle penalties
YRS	length of planning period, yr

Notes:

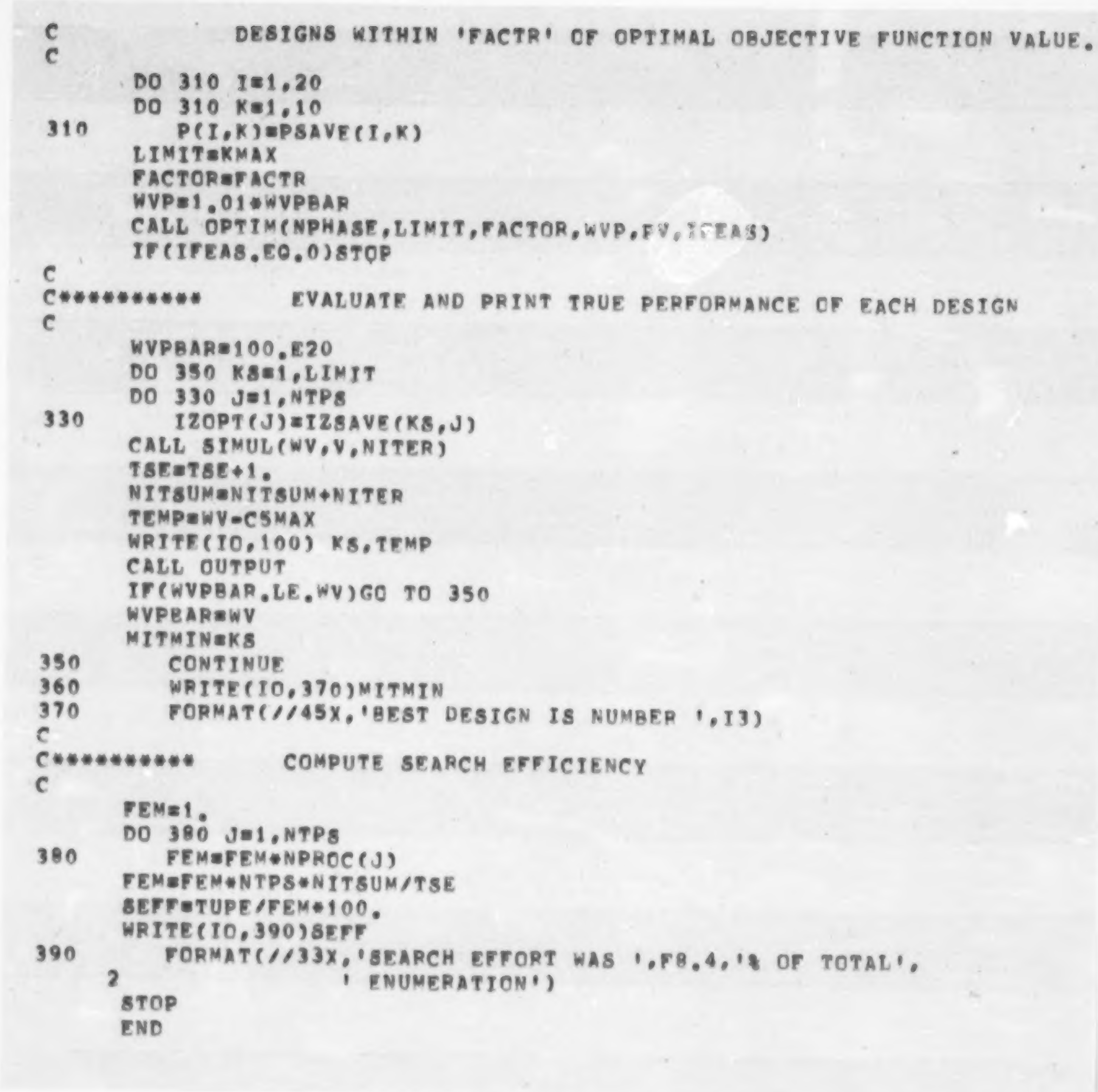
1. Design criteria are listed in the definition of V.
2. Sludge types consist of the following:

I = 1 primary	J = 1 raw
I = 2 secondary	J = 2 lime stabilized
I = 3 mixed primary and secondary	J = 3 digested
	J = 4 digested & elutriated
	J = 5 heat treated

3. Waste stream components are defined in SMATX.

```
C***********************************************************************
C*                                                                     *
C*                          EXECOP - MAIN                              *
C*                                                                     *
C*      EXEC/OP - OPTIMIZATION VERSION OF EPA EXECUTIVE PROGRAM        *
C*                                                                     *
C*                          VERSION 1.2                                *
C*                                                                     *
C*      SELECTS BEST COMBINATION OF UNIT PROCESSES FOR TREATING        *
C*      WASTEWATER AND DISPOSING OF RESIDUAL SLUDGES.                  *
C*      SELECTION CRITERIA INCLUDES COST, ENERGY, LAND UTILIZATION,    *
C*      AND A SUBJECTIVE PROCESS UNDESIREABILITY RATING.               *
C*      PROGRAM CAN ALSO IDENTIFY UP TO 40 NEXT-BEST DESIGNS.          *
C*                                                                     *
C*               WRITTEN BY L. ROSSMAN, U.S. EPA, MERL                 *
C*                          DECEMBER 1978                              *
C*               REVISED -  JANUARY 1980                               *
C*                                                                     *
C*                                                                     *
C***********************************************************************
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     1       INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     2       ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     3       CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
     2             NTPS,NTPU,JSTPM(22),JSIDE(20),P(20,10),
     3             IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2             IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      COMMON/TABLES/ DUMMY(525)
      DIMENSION V(10),WVSAVE(10)
      DIMENSION PSAVE(20,10)
      EQUIVALENCE (PSAVE(1,1),IZSAVE(1,1))
C
C**********        ASSIGN INPUT AND OUTPUT DEVICE NUMBERS
C
      INP=1
      IO=2
      OPEN (UNIT=1, NAME='EXIN.DAT', TYPE='OLD')
      OPEN (UNIT=2, NAME='EXOUT.DAT', TYPE='NEW')
C
C**********        READ IN INPUT DATA
C
      ISW=0
      CALL INPUT(ISW)
      IF (ISW .LT. 0) STOP
C
C**********        INITIALIZE COUNTERS AND PENALTIES
C
      MITMAX=10
      MITER=1
      TUPE=0.
      TSE=0.
      NITSUM=0
      WVPBAR=1.E20
```

```
        NPHASE=1
 25     DO 30 I=1,20
        SMATX(I,1)=PINFLO(I)
        DO 30 K=1,10
        PSAVE(I,K)=0.
 30     P(I,K)=0.
        P(2,5)=-10000.
        P(2,6)=-10000.
C
C**********      IF SYSTEM DESIGN CHOICES ARE PART OF INPUT THEN EVALUATE
C                AND PRINT SYSTEM PERFORMANCE
C
        IF (ISW .EQ. 0) GO TO 40
        CALL SIMUL(WV,V,NITER)
        TSE=TSE+1.
        NITSUM=NITSUM+NITER
        CALL OUTPUT
        IF (V(1) .GE. 1.E20) GO TO 55
        IF (KMAX .GE. 1) GO TO 270
        STOP
C
C               OPTIMIZATION PHASE
C               ------------------
C
C
40      WRITE(IO,400)
400      FORMAT(////,46X,'CANDIDATE OPTIMAL DESIGNS'/46X,25('_'))
C
C**********       PERFORM SYSTEM OPTIMIZATION USING PENALTY TERMS TO
C            ACCOUNT FOR SLUDGE RECYCLE FLOWS.
C
45        IF(MITER.GT.MITMAX)GO TO 300
       WVP=1.01*WVPBAR
       LIMIT=1
         CALL OPTIM(NPHASE,LIMIT,1.0,WVP,PV,IFEAS)
       IF(IFEAS.GT.0)GO TO 90
55       WRITE(IO,50)
50       FORMAT(/33X,'*** NO ACCEPTABLE CANDIDATE DESIGN CAN BE ',
     2               'FOUND ***')
       IF(MITER.EQ.1)STOP
       GO TO 300
C
C**********       EVALUATE PERFORMANCE OF CANDIDATE OPTIMAL SYSTEM WITH
C            RECYCLE FLOWS PROPERLY ACCOUNTED FOR
C
90       CALL SIMUL(WV,V,NITER)
      TSE=TSE+1.
      NITSUM=NITSUM+NITER
      TEMP=WV-C5MAX
      WRITE(IO,100) MITER,TEMP
100      FORMAT(////52X,'DESIGN ',I3/52X,10('_')//
     2          39X,' EXACT SYSTEM VALUE',6X,F12.3)
      TEMP=WVP-C5MAX
      WRITE(IO,105) TEMP,PV
105      FORMAT(39X,' APPROX. SYSTEM VALUE',4X,F12.3/
C
C***********      IF OBJECTIVE FUNCTION VALUE WAS REACHED ONCE BEFORE, STO
C              WITH CURRENT INCUMBENT DESIGN AS OPTIMAL
C
          IF(MITER.EQ.1)GO TO 250
      J2=MITER-1
      DO 240 JJ=1,J2
      IF(WVSAVE(JJ).EQ.WV)GO TO 295
240      CONTINUE
C
C***********      DETERMINE IF CANDIDATE DESIGN MEETS ALL PERFORMANCE
C              CRITERIA CONSTRAINTS
C
250      IFEAS=1
      DO 230 K=1,10
      IF(V(K).GT.B(K))IFEAS=0
230      CONTINUE
C
C***********      PRINT CANDIDATE DESIGN AND SAVE ITS OBJECTIVE FUNCTION
C              VALUE. IF IT IS BETTER THAN THE INCUMBENT DESIGN, MAKE
C              IT THE NEW INCUMBENT.
C
      CALL OUTPUT
      IF(IFEAS.EQ.0)WRITE(IO,235)
235      FORMAT(/32X,'*** DESIGN DOES NOT MEET ALL CONSTRAINT ',
     2              'CRITERIA ***')
      WVSAVE(MITER)=WV
      IF(IFEAS.EQ.0)GO TO 260
      IF(WVPBAR.LE.WV) GO TO 260
      WVPBAR=WV
      DO 255 I=1,20
      DO 255 K=1,10
255      PSAVE(I,K)=P(I,K)
      MITMIN=MITER
260      MITER=MITER+1
      IF(MITER.GT.MITMAX)GO TO 300
C
C***********      COMPUTE NEW RECYCLE PENALTIES AND BEGIN ANOTHER
C              DESIGN OPTIMIZATION ITERATION
C
270      CALL PNALTY(V)
      GO TO 45
C
295      WRITE(IO,305) JJ
305      FORMAT(/45X,'SAME SYSTEM AS DESIGN ',I3)
C
C              NEXT - BEST PHASE
C              ----------------
C
300      NPHASE=2
      IF(KMAX.LE.1) GO TO 360
      WRITE(IO,405) KMAX
405      FORMAT(////,48X,I2,' BEST DESIGNS'/48X,15('_'))
C
C***********      SET RECYCLE PENALTIES EQUAL TO THOSE OF OPTIMAL DESIGN.
C              REPEAT OPTIMIZATION ALGORITHM SAVING THE FIRST 'KMAX'
```



```
C             DESIGNS WITHIN 'FACTR' OF OPTIMAL OBJECTIVE FUNCTION VALUE.
C
      DO 310 I=1,20
      DO 310 K=1,10
310      P(I,K)=PSAVE(I,K)
      LIMIT=KMAX
      FACTOR=FACTR
      WVP=1.01*WVPBAR
      CALL OPTIM(NPHASE,LIMIT,FACTOR,WVP,FV,IFEAS)
      IF(IFEAS.EQ.0)STOP
C
C**********       EVALUATE AND PRINT TRUE PERFORMANCE OF EACH DESIGN
C
      WVPBAR=100.E20
      DO 350 KS=1,LIMIT
      DO 330 J=1,NTPS
330      IZOPT(J)=IZSAVE(KS,J)
      CALL SIMUL(WV,V,NITER)
      TSE=TSE+1.
      NITSUM=NITSUM+NITER
      TEMP=WV-C5MAX
      WRITE(IO,100) KS,TEMP
      CALL OUTPUT
      IF(WVPBAR.LE.WV)GO TO 350
      WVPBAR=WV
      MITMIN=KS
350      CONTINUE
360      WRITE(IO,370)MITMIN
370      FORMAT(//45X,'BEST DESIGN IS NUMBER ',I3)
C
C**********       COMPUTE SEARCH EFFICIENCY
C
      FEM=1.
      DO 380 J=1,NTPS
380      FEM=FEM*NPROC(J)
      FEM=FEM*NTPS*NITSUM/TSE
      SEFF=TUPE/FEM*100.
      WRITE(IO,390)SEFF
390      FORMAT(//33X,'SEARCH EFFORT WAS ',F8.4,'% OF TOTAL',
     2                 ' ENUMERATION')
      STOP
      END
```

```
C
C*****************************************************
C*                                                   *
C*            INPUT SUBROUTINE                       *
C*                                                   *
C*****************************************************
C
      SUBROUTINE INPUT(ISW)
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     1         INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     2         ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     3         CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
     2               NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     3               IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2               IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      COMMON/TABLES/VACF7(3,5,5),VACF8(3,5,5),VACF9(3,5,5),VACF10(3,5,5)
     2      ,CENT4(3,5,5),CENT5(3,5,5),CENT6(3,5,5)
      DIMENSION TITLE(40), RECORD(40)
C
C**********     READ IN JOB TITLE
C
      READ(INP,10)TITLE
10      FORMAT(40A2)
      WRITE(IO,5)
5      FORMAT('1'/50X,15('*')/50X,'*',13X,'*'/50X,'*   EXEC/OP   *'/
     2          50X,'*',13X,'*'/50X,'* VERSION 1.2 *'/50X,'*',13X,'*'/
     3          50X,15('*'))
      WRITE(IO,15)
15      FORMAT(//49X,'EXECUTIVE PROGRAM'/46X,'(OPTIMIZATION VERSION)'
     2         /56X,'FOR'/33X,'PRELIMINARY SYNTHESIS OF WASTE ',
     3         'TREATMENT SYSTEMS')
      WRITE(IO,20)
20      FORMAT(//39X,'U.S. ENVIRONMENTAL PROTECTION AGENCY'/36X,
     2  'MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY'/39X,
     3  'SYSTEMS AND ECONOMIC ANALYSIS SECTION'/46X,
     4  'CINCINNATI, OHIO 45268')
      WRITE(IO,25) TITLE
25      FORMAT(////13X,84('*')/13X,'*',82X,'*'/13X,'* ',40A2,' *'
     2        /13X,'*',82X,'*'/13X,84('*'))
C
C**********     READ IN INFLUENT WASTE CHARACTERISTICS, EFFLUENT
C           DISCHARGE STANDARDS, AND ECONOMIC DATA.
C
      PINFLO(1)=1.
      PINFLO(20)=0.
      READ(INP,1,ERR=1000) (PINFLO(I),I=2,19)
      READ(INP,1,ERR=1000) (EFFSTD(I),I=1,5)
      READ(INP,1,ERR=1000) CCI,WPI,RI,YRS,DHR,PCT,CKWH,RATIO,CF
      AF=RI*(1.+RI)**YRS/((1.+RI)**YRS-1.)
C
C**********     READ IN # WASTEWATER PROCESS STAGES,
C             # SECONDARY SLUDGE PROCESS STAGES,
C             # PRIMARY SLUDGE PROCESS STAGES, TOTAL # PROCESS UNITS,
C             AND SLUDGE RECYCLE RETURN STAGE
C
      READ(INP,2,ERR=1000)NWPS,NSSPS,NPSPS,NTPU,JRECYC
C
C**********        RECORD STREAM NOS. OF INFLUENT AND EFFLUENT TO ALL
C             TREATMENT TRAINS
C
      NTPS=NWPS+NPSPS+NSSPS
      JSTRM(1)=1
      JSTRM(2)=NWPS
      JSTRM(3)=JSTRM(2)+1
      JSTRM(4)=JSTRM(3)+NSSPS-1
      JSTRM(5)=JSTRM(4)+1
      JSTRM(6)=JSTRM(5)+NPSPS-1
      JSTRM(7)=JSTRM(6)+1
      JSTRM(10)=JSTRM(7)+NWPS-1
      JSTRM(11)=JSTRM(10)+1
      JSTRM(12)=JSTRM(11)+NSSPS-1
      JSTRM(13)=JSTRM(12)+1
      JSTRM(14)=JSTRM(13)+NPSPS-1
      JSTRM(15)=JSTRM(14)+1
      JSTRM(16)=JSTRM(15)+1
      JSTRM(17)=JSTRM(16)+1
      JSTRM(20)=JRECYC
      DO 30 J=1,NTPS
30      NPROC(J)=0
      N=0
C
C**********        READ IN STAGE ASSIGNMENTS FOR SLUDGE STREAMS FROM
C             WASTEWATER TREATMENT
C
      READ(INP,2,ERR=1000) (JSIDE(I),I=1,NWPS)
      JJ=JSTRM(3)
      DO 32 I=JJ,NTPS
32      JSIDE(I)=JRECYC
C
C**********        READ IN INPUT DESIGN DATA FOR UNIT PROCESS OPTIONS
C
      DO 33 I=1,NTPS
33      C5JMAX(I)=0.
      WRITE(IO,35)
35      FORMAT(////47X,'PROCESS ALTERNATIVES'/47X,20('_'))
      WRITE(IO,40)
40      FORMAT(//' OPTION  PROCESS  STAGE  SIDESTREAM'/
     2    '   NO.      NO.      NO.   DESTINATION',37X,'REMARKS'/
     3    ' ______  _______  _____  ___________',2X,80('_'))
      DO 60 K=1,NTPU
      READ(INP,3,ERR=1000)J,N,IPROC,EMAX,UDR(N)
      IF (EMAX .GT. C5JMAX(J)) C5JMAX(J)=EMAX
      READ(INP,45,ERR=1000)(TITLE(JJ),JJ=1,40)
45      FORMAT(40A2)
      WRITE(IO,50) N,IPROC,J,JSIDE(J), (TITLE(JJ),JJ=1,40)
50      FORMAT(1X,I4,3I8,9X,40A2)
      NPROC(J)=NPROC(J)+1
      KPROC(NPROC(J),J)=N
      IP(N)=IPROC
      IF(IPROC.EQ.0)JSTRM(22)=N
      IF(IPROC.EQ.0)GO TO 60
      READ(INP,1,ERR=1000)(DMATX(I,N),I=1,16)
C
C***** CHECK IF PROCESS REQUIRES SUPPLEMENTARY INPUT DATA
      IF(IPROC.EQ.7)GO TO 51
      IF(IPROC.EQ.17)GO TO 53
      IF(IPROC.EQ.25)GO TO 55
      GO TO 60
51      L=DMATX(6,N)
      READ(INP,1,ERR=1000)((VACF7(I,JJ,L),I=1,3),JJ=1,5)
      READ(INP,1,ERR=1000)((VACF8(I,JJ,L),I=1,3),JJ=1,5)
      READ(INP,1,ERR=1000)((VACF9(I,JJ,L),I=1,3),JJ=1,5)
      READ(INP,1,ERR=1000)((VACF10(I,JJ,L),I=1,3),JJ=1,5)
      GO TO 60
53      L=DMATX(3,N)
      READ(INP,1,ERR=1000)((CENT4(I,JJ,L),I=1,3),JJ=1,5)
      READ(INP,1,ERR=1000)((CENT5(I,JJ,L),I=1,3),JJ=1,5)
      READ(INP,1,ERR=1000)((CENT6(I,JJ,L),I=1,3),JJ=1,5)
      GO TO 60
55      L=DMATX(1,N)
      READ(INP,1,ERR=1000) (DMATX(I,L),I=1,16)
      L=DMATX(2,N)
      READ(INP,1,ERR=1000) (DMATX(I,L),I=1,16)
      GO TO 60
60      CONTINUE
C
C**********        PRINT OUT EFFLUENT DISCHARGE STANDARDS
C             AND INCREASE THEM SLIGHTLY TO AVOID FALSE INFEAS-
C             IBILITY DUE TO ROUNDOFF ERRORS
C
      WRITE(IO,65)
65      FORMAT(////44X,'EFFLUENT DISCHARGE STANDARDS',/44X,28('_')/)
      WRITE(IO,70)(EFFSTD(I),I=1,5)
70      FORMAT(41X,' 5-DAY BOD, MG/L',7X,F10.2/41X,' SUSPENDED SOLIDS',
     2         ', MG/L',F10.2/41X,' AMMONIA - N, MG/L',5X,F10.2/
     3         41X,' NITRATE - N, MG/L',5X,F10.2/41X,' PHOSPHORUS, MG/L',
     4         6X,F10.2)
      DO 75 I=1,5
75      EFFSTD(I)=1.001*EFFSTD(I)
C
C**********        READ IN SELECTION CRITERIA WEIGHTS AND CONSTRAINT LIMITS
C
      DO 115 K=1,10
115       W(K)=0.
      WRITE(IO,120)
120       FORMAT(////48X,'SELECTION CRITERIA'/48X,18('_')//)
      WRITE(IO,125)
125       FORMAT(32X,'CRITERION',25X,'WEIGHT',11X,'LIMIT',
     2  /32X,9('_'),25X,6('_'),11X,5('_')/)
      READ(INP,1,ERR=1000)(W(K),K=1,8)
      READ(INP,1,ERR=1000)(B(K),K=1,8)
      WRITE(IO,130)(W(K),B(K),K=1,4)
130       FORMAT(25X,' 1.  INITIAL CONSTR. COST, M$   ',6X,2(F10.2,8X),
     2         /25X,' 2.  ANNUAL O & M COST, $/MG',9X,2(F10.2,8X),
     3          /25X,' 3.  TOTAL ANNUAL COST, $/MG',9X,2(F10.2,8X),
     4          /25X,' 4.  ENERGY CONSUMED, KWH/MG',9X,2(F10.2,8X))
      WRITE(IO,135)(W(K),B(K),K=5,8)
 135      FORMAT(25X,' 5.  ENERGY PRODUCED, KWH/MG',9X,2(F10.2,8X),
     2          /25X,' 6.  NET ENERGY CONSUMED, KWH/MG',5X,2(F10.2,8X),
     3          /25X,' 7.  LAND REQUIRED, ACRES',12X,2(F10.2,8X),
     4          /25X,' 8.  UNDESIREABILITY INDEX',11X,2(F10.2,8X))
C
C**********      PRINT OUT ECONOMIC DATA AND ADJUST COST INDEXES TO JAN 1971
C
      WRITE(IO,200)
 200      FORMAT(////51X,'ECONOMIC DATA'/51X,13('_')/)
      WRITE(IO,210) CCI,WPI,DHR,PCT
 210      FORMAT(33X,' CONSTRUCTION COST INDEX',12X,F12.4/
     2          33X,' WHOLESALE PRICE INDEX',14X,F12.4/
     3          33X,' DIRECT HOURLY WAGE, $/HR',11X,F12.4/
     4          33X,' FRACTION CHARGED TO INDIRECT WAGES',1X,F12.4)
      WRITE(IO,220) RATIO,CKWH,CF,RI,AF
 220      FORMAT(33X,' COST ESCALATOR FOR MISC. FEES',6X,F12.4/
     2          33X,' COST OF ELECTRICITY, $/KWH',9X,F12.4/
     3          33X,' BTU TO KWH CONVERSION EFF.',9X,F12.4/
     4          33X,' DISCOUNT RATE',22X,F12.4/
     5          33X,' CAPITAL RECOVERY FACTOR',12X,F12.4/)
      CCI=CCI/1.506*1.845
      WPI=WPI/1.122
C
C**********      CHANGE ENERGY PRODUCTION CRITERION TO DIFFERENCE BETWEEN
C          MAXIMUM POSSIBLE AND ACTUAL PRODUCTION
C
      C5MAX=0.
      DO 160 J=1,NTPS
 160      C5MAX=C5MAX+C5JMAX(J)
      B(5)=C5MAX-B(5)
      B(6)=C5MAX+B(6)
      C5MAX=W(5)*C5MAX
C
C**********      READ IN # NEXT-BEST DESIGNS DESIRED WITHIN 'FACTR' OF
C          OPTIMAL OBJECTIVE FUNCTION VALUE
C
      READ(INP,4,ERR=1000) KMAX,FACTR
      FACTR=1.+FACTR
C
C**********      FOR A SINGLE DESIGN EVALUATION OR TO OVERIDE DEFAULT
C          PENALTY VALUES, READ IN OPTION NOS. FOR PROCESS CHOICE
C          AT EACH STAGE OF SYSTEM
C
      READ(INP,2,END=80,ERR=1000)(IZOPT(J),J=1,NTPS)
      ISW=1
 80     RETURN
 1      FORMAT(8F10.0)
 2      FORMAT(8I10)
 3      FORMAT(3I10,2F10.0)
 4      FORMAT(I10,F10.0)
C
C**********      INPUT ERROR INDICATOR
C
```

```
1000       WRITE(IO,1001)
1001    FORMAT(//' *** ERROR OCCURRED AT FOLLOWING LINE OF INPUT: ***'/)
       BACKSPACE INP
       READ(INP,10)(RECORD(I),I=1,40)
       WRITE(IO,1002)(RECORD(I),I=1,40)
1002       FORMAT(1X,40A2)
       ISW=-1
       RETURN
       END
```

```
C
C
C************************************************************
C                                                           *
C            OUTPUT SUBROUTINE                              *
C                                                           *
C************************************************************
C
      SUBROUTINE OUTPUT
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2         INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3         ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS
     4         CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
     2               NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     3               IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2               IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      DIMENSION V(10)
C
C
      WRITE(IO,20)
20      FORMAT(//' STAGE  PROCESS   SLUDGE',6X,'CONSTR    ',
     2            ' ANN O&M   TOTAL ANN   ENER USE  ENER PROD   ',
     3           'NET ENER  LAND REQD  UNDESIRE-')
      WRITE(IO,22)
22      FORMAT(' NO.   OPTION   TONS/DAY     COST M$   COST $/MG',
     2           '  COST $/MG    KWH/MG     KWH/MG     KWH/MG     ',
     3         'ACRES     ABILITY')
      WRITE(IO,24)
24      FORMAT(1X,5('_'),2X,7('_'),2X,8('_'),2X,8(2X,9('_')))
      STOT=0.
      DO 30 K=1,10
30      V(K)=0.
C
      DO 120 J=1,NTPS
      N=IZOPT(J)
      IPROC=IP(N)
      IF(IPROC.EQ.0)GO TO 120
      IF(J.GT.JSTRM(2))GO TO 50
      OS2=NTPS+J
      S2=SMATX(2,OS2)*SMATX(10,OS2)*8.33/2000.
      STOT=STOT+S2
      GO TO 60
C
50      S2=SMATX(2,J)*SMATX(10,J)*8.33/2000.
C
60      DO 55 K=1,10
      IF (C(J,K) .GE. 1.E20) GO TO 160
55      V(K)=V(K)+C(J,K)
      WRITE(IO,90) J,N,S2,(C(J,K),K=1,8)
90      FORMAT(2X,I2,6X,I2,5X,F8.2,2X,F11.4,7F11.2)
C
120      CONTINUE
```

```
      WRITE(IO,130)
130       FORMAT(17X,8('_'),2X,8(2X,9('_')))
      WRITE(IO,140)STOT,(V(K),K=1,8)
140       FORMAT(' SYSTEM VALUES   ',F8.2,2X,8F11.2)
      WRITE(IO,150) JSTRM(21)
150       FORMAT(/34X,'PRIMARY AND SECONDARY SLUDGES MIXED AT STAGE ',
     2          I2)
      GO TO 175
160       WRITE(IO,170)
170       FORMAT(/' *** SYSTEM INFEASIBILE BEYOND THIS POINT.',
     2         ' CHECK FOR VIOLATION OF EFFLUENT STDS. OR ',
     3         'PROHIBITED PROCESS ARRANGEMENT. ***')
175       IF (KMAX .GT. 0) GO TO 145
      WRITE(IO,190)
190      FORMAT(////40X,'PROCESS PERFORMANCE CHARACTERISTICS'/40X,35('_')
     2   //49X,'VOLUME FLOW, MGD'/49X,'CONCENTRATION, MG/L'/15X,
     4   'CONSULT PROGRAM REFERENCE MANUAL FOR MEANING OF PROCESS INPUT',
     5   ' AND OUTPUT DESIGN DATA.'//)
      DO 260 J=1,NTPS
      N=IZOPT(J)
      IPROC=IP(N)
      IF(IPROC.EQ.0)GO TO 260
      IS1=J
      OS1=J+1
      IF(J.EQ.JSTRM(2))OS1=JSTRM(15)
      IF(J.EQ.JSTRM(4))OS1=JSTRM(16)
      IF(J.EQ.JSTRM(6))OS1=JSTRM(17)
      OS2=NTPS+J
      WRITE(IO,200) J,N
200       FORMAT(//46X,'STAGE ',I2,'   PROCESS OPTION ',I2/46X,28('_'))
      IF (J .EQ. JSTRM(20)) WRITE(IO,202)
202       FORMAT(/13X,'NOTE: INFLUENT (EFFLUENT FROM PREVIOUS STAGE) ',
     2  'INCLUDES RETURN SIDESTREAMS FROM SLUDGE TREATMENT')
      IF (J .EQ. JSTRM(21)) WRITE(IO,204)
204       FORMAT(/17X,'NOTE: INFLUENT (EFFLUENT FROM PREVIOUS STAGE) ',
     2  'INCLUDES SECONDARY SLUDGE TRAIN EFFLUENT')
      WRITE(IO,210)
210       FORMAT(/51X,'INPUT DESIGN DATA:')
      WRITE(IO,220) (I,I=1,8)
      WRITE(IO,225) (DMATX(I,N),I=1,8)
      WRITE(IO,220) (I,I=9,16)
      WRITE(IO,225) (DMATX(I,N),I=9,16)
220       FORMAT(13X,8(I10,2X))
225       FORMAT(13X,8F12.3)
      WRITE(IO,230)
230       FORMAT(/51X,'OUTPUT DESIGN DATA:')
      WRITE(IO,240) (I,I=1,10)
      WRITE(IO,245) (OMATX(I,N),I=1,10)
      WRITE(IO,240) (I,I=11,20)
      WRITE(IO,245) (OMATX(I,N),I=11,20)
240       FORMAT(1X,10(I10,2X))
245       FORMAT(1X,10F12.3)
      WRITE(IO,250)
250       FORMAT(/35X,'INFLUENT / EFFLUENT / SIDESTREAM CHARACTERISTICS:'/
     2    22X,'Q',9X,'SOC',8X,'SNBC',9X,'SON',9X,'SOP',9X,
     3    'SFM',8X,'SBOD',9X,'VSS',9X,'TSS')
```

```
      WRITE(IO,265) (SMATX(I,IS1),I=2,10),(SMATX(I,OS1),I=2,10),
     2               (SMATX(I,OS2),I=2,10)
      WRITE(IO,255)
255      FORMAT(20X,'DOC',8X,'DNBC',10X,'DN',10X,'DP',9X,'DFM',9X,'ALK',
     2         8X,'DBOD',9X,'NH3',9X,'NO3')
      WRITE(IO,265) (SMATX(I,IS1),I=11,19),(SMATX(I,OS1),I=11,19),
     2               (SMATX(I,OS2),I=11,19)
265      FORMAT(' INFLUENT:    ',9F12.3/
     2         ' EFFLUENT:    ',9F12.3/
     3         ' SIDESTRM:    ',9F12.3)
260      CONTINUE
145      RETURN
      END
```

```
C
C*****************************************************************
C                                                                *
C            SYSTEM SIMULATION SUBROUTINE                        *
C                                                                *
C*****************************************************************
C
      SUBROUTINE SIMUL(WV,V,NITER)
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2         INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3         ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     4         CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
     2               NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     3               IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2               IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      DIMENSION V(10),TRECYC(20),RECYC(20)
      DATA NITMAX/20/,EPS1/.001/,EPS2/.0001/
C
      DO 5 I=1,20
5      RECYC(I)=0.
      DELSUM=0.
      NITER=0
C
C**********      EVALUATE SYSTEM PERFORMANCE WITH CURRENT VALUE
C            OF RECYCLE FLOW
C
90      NITER=NITER+1
      IF(NITER.GT.NITMAX) GO TO 100
      DO 10 I=1,20
      TRECYC(I)=RECYC(I)
10      SMATX(I,1)=PINFLO(I)
      SUMOLD=DELSUM
      CALL SYSTEM(WV,V,RECYC)
C
C**********      MIX SIDESTREAMS OFF OF SLUDGE PROCESSES TOGETHER
C            PROGRAMMER'S NOTE: SET J = 2ND DIMENSION OF 'SMATX'
C
35      J=45
      J1=JSTRM(3)
      J2=JSTRM(6)
      J3=JSTRM(20)
      CALL SMIX(J,J1,J2,J3)
      DO 40 I=2,20
40      RECYC(I)=SMATX(I,J)
C
C**********      CHECK FOR CONVERGENCE (ALL RECYCLE COMPONENTS CHANGE
C            BY LESS THAN .1% OR SUM OF DIFFERENCES BETWEEN SUCCESSIVE
C            ITERATIONS CHANGES BY LESS THAN .01%)
C
      ISTOP=1
      DELSUM=0.
      DO 50 I=2,20
      DEL=ABS(RECYC(I)-TRECYC(I))
      DELSUM=DELSUM+DEL
      IF(DEL.GT.EPS1*RECYC(I)) ISTOP=0
50      CONTINUE
      IF(ABS(DELSUM-SUMOLD).LT.EPS2*DELSUM) GO TO 100
      IF(ISTOP.EQ.1) GO TO 100
      GO TO 90
100      RETURN
      END
```

```
C
C
C*********************************************************************
C                                                                    *
C          SYSTEM OPTIMIZATION SUBROUTINE                            *
C                                                                    *
C*********************************************************************
C
      SUBROUTINE OPTIM(NPHASE,LIMIT,FACTOR,WVP,PV,IFEAS)
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     1           INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     2           ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     3           CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
                      NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     2                IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2                IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      DIMENSION LSAVE(20),IZBAR(20)
      DIMENSION VTEMP(10),PTEMP(10),VJ(20,10),PJ(20,10)
      DIMENSION RECYC(20)
C
      IFEAS=0
      KOUNT=0
      RECYC(2)=0.
      DO 5 K=1,10
      VJ(1,K)=0.
5      PJ(1,K)=0.
      JSTRM(21)=JSTRM(17)
      J=1
C
C**********       MIX TOGETHER ALL WASTE STREAMS INFLUENT TO STAGE J.
C            FIND NEXT OPTION IN PROCESS LIST AT STAGE J.
C
20       L=1
      CALL STRMIN(J,RECYC)
25       LSAVE(J)=L
      N=KPROC(L,J)
      IPROC=IP(N)
C
C**********       ESTABLISH INFLUENT, EFFLUENT, AND SIDESTREAM ID NOS.
C            AND EVALUATE PROCESS PERFORMANCE
C
      IS1=J
      IS2=0
      OS1=J+1
      IF(J.EQ.JSTRM(2))OS1=JSTRM(15)
      IF(J.EQ.JSTRM(4))OS1=JSTRM(16)
      IF(J.EQ.JSTRM(6))OS1=JSTRM(17)
      OS2=NTPS+J
80       CALL UNIT(J,IPROC)
C
C**********       SEE IF OBJECTIVE FUNCTION VALUE UP TO STAGE J
C            IS BETTER THAN CURRENT OPTIMAL SYSTEM VALUE
```

```
C
      PSUM=0.
      VSUM=0.
      DO 85 K=1,10
      VTEMP(K)=VJ(J,K)+C(J,K)
      PTEMP(K)=PJ(J,K)+CP(K)
      IF(K.EQ.5)VTEMP(K)=VJ(J,K)+C5JMAX(J)-C(J,K)
      IF(K.EQ.6)VTEMP(K)=VJ(J,K)+C5JMAX(J)+C(J,K)
      IF(VTEMP(K)+PTEMP(K).GT.B(K))GO TO 90
75      VSUM=VSUM+W(K)*VTEMP(K)
      PSUM=PSUM+W(K)*PTEMP(K)
85      CONTINUE
      IF(FACTOR*WVP.LE.VSUM+PSUM)GO TO 90
C
C**********      ADD CURRENT PROCESS OPTION TO SOLUTION AND UPDATE
C            SYSTEM CRITERIA VALUES.
C
      IZOPT(J)=N
      J=J+1
      DO 95 K=1,10
      VJ(J,K)=VTEMP(K)
95      PJ(J,K)=PTEMP(K)
      IF(J.LE.NTPS)GO TO 20
C
C**********      IF NEW COMPLETE DESIGN WAS ARRIVED AT, RECORD ITS
C            OBJECTIVE FUNCTION VALUE
C
      IFEAS=1
      WVPK=VSUM+PSUM
      IF(WVPK.GE.WVP)GO TO 105
      WVP=WVPK
      PV=PSUM
      DO 100 J=1,NTPS
100      IZBAR(J)=IZOPT(J)
1000           FORMAT(/E12.4,14I4)
C
C**********      IF IN NEXT-BEST PHASE OF ALGORITHM, INSERT NEW DESIGN
C            INTO LIST
C
105      IF(NPHASE.EQ.1)GO TO 180
      CALL SAVE(KOUNT,WVPK,LIMIT)
C
180      J=NTPS
C
C**********      MOVE ON TO NEXT PROCESS OPTION AT CURRENT STAGE.
C            IF NO MORE OPTIONS THEN MOVE BACK ONE STAGE
90      L=LSAVE(J)+1
      IF(L.LE.NPROC(J))GO TO 25
      J=J-1
      IF(J.GE.1)GO TO 90
C
C**********      IF CANNOT MOVE BACK ONE STAGE THEN STOP THE SEARCH
C
      DO 190 J=1,NTPS
190      IZOPT(J)=IZBAR(J)
      LIMIT=KOUNT
      RETURN
      END
```

```
C
C
C*************************************************************
C                                                            *
C            NEXT-BEST DESIGN SAVE SUBROUTINE                *
C                                                            *
C*************************************************************
C
      SUBROUTINE SAVE(KOUNT,WVPK,LIMIT)
C
      COMMON/PROC/IDUMM1(223),NTPS,IDUMM2(43),P(20,10),
     2             IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/DUMMY(280),IZSAVE(40,20),C5JMAX(20),C5MAX,
     2             KMAX,FACTR,TUPE
      DIMENSION VSAVE(40)
      DATA VSAVE/40*0./
C
      IF (KOUNT .EQ. 0) GO TO 120
C
C**********      LOCATE POSITION OF LARGEST ENTRY IN VSAVE AND MAKE SURE
C            NEW DESIGN WAS NOT PREVIOUSLY RECORDED IN VSAVE
C
      VMAX=0.
      DO 110 M=1,KOUNT
      IF (WVPK .EQ. VSAVE(M)) GO TO 180
      IF (VSAVE(M) .LE. VMAX) GO TO 110
      VMAX=VSAVE(M)
      KVMAX=M
110      CONTINUE
      IF (WVPK .GE. VMAX) GO TO 140
      IF (KOUNT .EQ. LIMIT) GO TO 130
C
C**********      LENGTH OF VSAVE IS LESS THAN LIMIT
C
120      KIN=KOUNT+1
      KOUNT=KIN
      GO TO 160
C
C**********      LENGTH OF VSAVE EQUALS LIMIT, REPLACE LARGEST ENTRY
C            WITH NEW DESIGN VALUE
C
130      KIN=KVMAX
      GO TO 160
C
C**********      NEW DESIGN VALUE IS LARGER THAN LARGEST ENTRY IN VSAVE.
C            IF LENGTH OF VSAVE = LIMIT, REJECT NEW DESIGN.
C
140      IF (KOUNT .EQ. LIMIT) GO TO 180
      VMAX=WVPK
      KVMAX=KOUNT+1
      GO TO 120
C
C**********      PLACE NEW DESIGN VALUE INTO VSAVE
C
160      VSAVE(KIN)=WVPK
      DO 170 J=1,NTPS
170      IZSAVE(KIN,J)=IZOPT(J)
C
180      RETURN
      END
```

```
C
C
C*******************************************************************
C                                                                  *
C            SYSTEM EVALUATION SUBROUTINE                          *
C                                                                  *
C*******************************************************************
C
      SUBROUTINE SYSTEM(WV,V,RECYC)
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     1         INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     2         ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     3         CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
     2                NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     3                IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2                IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      DIMENSION V(10),RECYC(20)
C
      WV=0.
      DO 5 K=1,10
5      V(K)=0.
      JSTRM(21)=JSTRM(17)
C
C***********      FOR EACH TREATMENT STAGE:
C
      DO 90 J=1,NTPS
C
C******      MIX TOGETHER ALL INFLUENT STREAMS TO STAGE J AND
C      DETERMINE ALL ITS STREAM ID NOS.
      CALL STPMIN(J,RECYC)
      N=IZOPT(J)
      IPROC=IP(N)
      IS1=J
      IS2=0
      OS1=J+1
      IF(J.EQ.JSTRM(2))OS1=JSTRM(15)
      IF(J.EQ.JSTRM(4))OS1=JSTRM(16)
      IF(J.EQ.JSTRM(6))OS1=JSTRM(17)
      OS2=NTPS+J
C
C******      EVALUATE PROCESS PERFORMANCE AND UPDATE SYSTEM CRITERIA
80      CALL UNIT(J,IPROC)
      DO 85 K=1,10
      IF(K.EQ.5)GO TO 81
      IF(K.EQ.6)GO TO 82
      V(K)=V(K)+C(J,K)
      GO TO 85
81      V(K)=V(K)+C5JMAX(J)-C(J,K)
      GO TO 85
82     V(K)=V(4)+V(5)
85      CONTINUE
90      CONTINUE
```

```
C
C***********      COMPUTE SYSTEM OBJECTIVE FUNCTION VALUE
C
      DO 95 K=1,10
95      WV=WV+W(K)*V(K)
      RETURN
      END
```

```
C
C
C*************************************************************
C                                                            *
C          UNIT PROCESS EVALUATION SUBROUTINE                *
C                                                            *
C*************************************************************
C
      SUBROUTINE UNIT(J,IPROC)
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     1        INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     2        ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     3        CF,EER,EEP,ALAND
      COMMON/PROC/ NPROC(20),KPROC(10,20),NWPS,NPSPS,NSSPS,
     2              NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     3              IZOPT(20),PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      COMMON/COST/ C(20,10),CP(10),B(10),W(10),UDR(50),
     2              IZSAVE(40,20),C5JMAX(20),C5MAX,KMAX,FACTR,TUPE
      COMMON/TABLES/VACF7(3,5,5),VACF8(3,5,5),VACF9(3,5,5),VACF10(3,5,5)
     2      ,CENT4(3,5,5),CENT5(3,5,5),CENT6(3,5,5)
      DIMENSION SAVE(20)
C
      TUPE=TUPE+1.
C
C**********      INITIALIZE ERROR INDICATOR
C
      IAERF=0
C
C**********      INITIALIZE OUTPUT STREAMS AND SELECTION CRITERIA
C
      DO 5 I=1,20
      SMATX(I,OS1)=SMATX(I,IS1)
5      SMATX(I,OS2)=0.
      I1=3
      IF (FPS(IS1) .EQ. 0.) I1=2
      IF (FPS(IS1) .EQ. 1.) I1=1
      FPS(OS1)=FPS(IS1)
      FPS(OS2)=0.
      IF (JSIDE(J) .EQ. JSTRM(5)) FPS(OS2)=1.
      ISC(OS1)=ISC(IS1)
      DO 15 II=1,5
      CCOST(II)=0.
      COSTO(II)=0.
      ACOST(II)=0.
15      CONTINUE
      DO 16 K=1,10
      CP(K)=0.
16      C(J,K)=0.
      EER=0.
      EEP=0.
      ALAND=0.
C
C**********      DETERMINE WHICH PROCESS SUBROUTINE TO CALL
C
```

```
      IF(IPROC.EQ.0)GO TO 560
      IF(SMATX(2,IS1).EQ.0.)GO TO 560
      GO TO(10,20,30,560,560,60,70,80,90,100,110,120,130,140,150,160,
     1        170,180,560,560,560,220,230,240,250,260),IPROC
      GO TO 560
C
C**********      PRELIMINARY TREATMENT
C
10      CALL PREL
      GO TO 500
C
C**********      PRIMARY SEDIMENTATION
C
20      CALL PRSET
      GO TO 500
C
C**********      ACTIVATED SLUDGE
C
30      CALL AERFS
      GO TO 500
C
C**********      ANAEROBIC DIGESTION
C
60      CALL DIG
C******      UPDATE SLUDGE STABILIZATION CODE
      ISC(OS1)=3
      GO TO 500
C
C**********      VACUUM FILTRATION
C
C******      DETERMINE TYPE OF PRIOR SLUDGE TREATMENT
70      J1=ISC(IS1)
      J2=J1
      I2=I1
      IF (J1 .LT. 10) GO TO 74
      J1=ISC(IS1)/10
      J2=ISC(IS1)-10*J1
      I1=1
      I2=2
C
C******      DETERMINE ACTUAL PROCESS PARAMETERS
74      L=DMATX(6,N)
      W1=FPS(IS1)
      W2=1.-W1
      DMATX(7,N)=W1*VACF7(I1,J1,L)+W2*VACF7(I2,J2,L)
        DMATX(8,N)=W1*VACF8(I1,J1,L)+W2*VACF8(I2,J2,L)
      DMATX(9,N)=W1*VACF9(I1,J1,L)+W2*VACF9(I2,J2,L)
      DMATX(10,N)=W1*VACF10(I1,J1,L)+W2*VACF10(I2,J2,L)
      CALL VACF
      GO TO 500
C
C**********      GRAVITY THICKENING
C
C******      DETERMINE ACTUAL PROCESS PARAMETERS
80      DMATX(9,N)=DMATX(2+I1,N)
      DMATX(10,N)=DMATX(5+I1,N)
      CALL THICK
      GO TO 500
C
C**********      ELUTRIATION
C
C******      SAVE FLOW OF WASHWATER STREAM
90      IS2=JSTRM(15)
      SAVE(2)=SMATX(2,IS2)
C******      DETERMINE ACTUAL PROCESS PARAMETERS
      DMATX(10,N)=DMATX(2+I1,N)
      DMATX(11,N)=DMATX(5+I1,N)
C
C******      DO NOT ALLOW ELUTRIATION IF PRECEEDED BY LIME STABILIZATION
      IF(ISC(IS1).EQ.2)GO TO 700
      IF(ISC(IS1)/10.EQ.2)GO TO 700
      IF(ISC(JSTRM(16)).EQ.2)GO TO 700
      CALL ELUT
      SMATX(2,IS2)=SAVE(2)
      IF (ISC(IS1) .EQ. 3) ISC(OS1)=4
      IF (ISC(IS1) .EQ. 33) ISC(OS1)=4
      GO TO 500
C
C**********      SLUDGE DRYING BEDS
C
C******      CHECK TO SEE THAT SLUDGE IS STABILIZED
100      IF (ISC(IS1) .LE. 1) GO TO 700
      IF (ISC(IS1) .LT.10) GO TO 105
      IF (ISC(IS1)/10 .LE. 1) GO TO 700
      IF (ISC(JSTRM(16)) .LE. 1)  GO TO 700
105      CONTINUE
C
C******      DETERMINE ACTUAL CAKE SOLIDS CONC.
      DMATX(7,N)=DMATX(2+I1,N)
      CALL SBEDS
      GO TO 500
C
C**********      TRICKLING FILTER
C
110      CALL TRFS
      GO TO 500
C
C**********      CHLORINATION
C
120      CALL CHLOR
      GO TO 500
C
C**********      FLOTATION THICKENING
C
130      CALL TFLOT
      GO TO 500
C
140      CALL MHINC
      GO TO 500
C
C**********      RAW WASTEWATER PUMPING
C
```

```
150      CALL RWP
      GO TO 500
C
C**********      SLUDGE HOLDING TANKS
C
160      CALL SHT
      GO TO 500
C
C**********      CENTRIFUGATION
C
C******      DETERMINE TYPE OF PRIOR SLUDGE TREATMENT
170      J1=ISC(IS1)
      J2=J1
      I2=I1
      IF (J1 .LT. 10) GO TO 174
      J1=ISC(IS1)/10
      J2=ISC(IS1)-10*J1
      I1=1
      I2=2
C
C******      DETERMINE ACTUAL PROCESS PARAMETERS
174      L=DMATX(3,N)
      W1=FPS(IS1)
      W2=1.-W1
         DMATX(4,N)=W1*CENT4(I1,J1,L)+W2*CENT4(I2,J2,L)
      DMATX(5,N)=W1*CENT5(I1,J1,L)+W2*CENT5(I2,J2,L)
      DMATX(6,N)=W1*CENT6(I1,J1,L)+W2*CENT6(I2,J2,L)
      CALL CENT
      GO TO 500
C
C**********      AEROBIC DIGESTION
C
180      CALL AEROB
C
C******      UPDATE SLUDGE STABILIZATION CODE
      ISC(OS1)=3
      GO TO 500
C
C**********      LAND DISPOSAL OF SLUDGE
C
C******      CHECK THAT SLUDGE IS STABILIZED
220      IF (ISC(IS1) .LE. 1) GO TO 700
      IF (ISC(IS1) .LT.10) GO TO 229
      IF (ISC(IS1)/10 .LE. 1) GO TO 700
      IF (ISC(JSTRM(16)) .LE. 1) GO TO 700
229      CALL LANDD
      GO TO 500
C
C**********      LIME STABILIZATION
C
230      CALL LIME
C
C******      ADJUST SLUDGE STABILIZATION CODE
      ISC(OS1)=2
      GO TO 500
C
```

```
C**********      ROTATING BIOLOGICAL CONTACTOR
C
240      CALL RBC
      GO TO 500
C
C**********      PRIMARY SEDIMENTATION - ACTIVATED SLUDGE - WASTE
C            ACTIVATED SLUDGE RETURNED TO PRIMARY SETTLER
C
250      CALL PSAS
C
C******      ADJUST FRACTION OF PRIMARY SLUDGE IN SLUDGE STREAM OS2
      FPS(OS2)=OMATX(3,N)
      GO TO 500
C
C**********      HEAT TREATMENT
C
C******      CHECK IF SLUDGE IS DIGESTED
260      DMATX(7,N)=0,
      IF(ISC(IS1),EQ,3) DMATX(7,N)=1,
      IF (ISC(IS1),EQ,33) DMATX(7,N)=1,
      DMATX(6,N)=FPS(IS1)
         CALL HEAT
C
C******      ADJUST SLUDGE STABILIZATION CODE
      ISC(OS1)=5
      GO TO 500
C
C**********      SUM SUB-UNIT COSTS
C
500      IF (IAERF .GT, 0) GO TO 700
      DO 540 II=1,5
      IF (ACOST(II)) 530,510,530
510      ACOST(II)=CCOST(II)*AF/PINFLO(2)/3650,
530      C(J,3)=C(J,3)+ACOST(II)+COSTO(II)
      C(J,1)=C(J,1)+CCOST(II)
      C(J,2)=C(J,2)+COSTO(II)
540      CONTINUE
C
C**********      EVALUATE SELECTION CRITERIA
C
      C(J,1)=C(J,1)/1,E6
      C(J,2)=C(J,2)*10,
      C(J,3)=C(J,3)*10,
      C(J,4)=EER/PINFLO(2)
      C(J,5)=EEP/PINFLO(2)
      C(J,6)=C(J,4)-C(J,5)
      C(J,7)=ALAND
      C(J,8)=UDR(N)
C
C**********      EVALUATE PENALTIES
C
      IF(J,LE,JSTRM(2))GO TO 600
      DO 555 K=1,10
        CP(K)=P(2,K)*SMATX(2,OS2)
      TEMP1=SMATX(2,OS2)
      DO 550 I=3,19
      TEMP2=SMATX(I,OS2)
      IF(I.EQ.9)TEMP2=SMATX(9,OS2)-SMATX(3,OS2)-SMATX(5,OS2)
     2  -SMATX(6,OS2)
      IF(I.EQ.13)TEMP2=SMATX(13,OS2)-SMATX(18,OS2)-SMATX(19,OS2)
      IF(TEMP2.LE.0.)TEMP2=0.
550      CP(K)=CP(K)+(P(I,K)*TEMP1*TEMP2)
555      CONTINUE
      GO TO 600
C
C**********      PROCESS IS NULL PROCESS
C
560      DO 570 I=1,20
      SMATX(I,OS1)=SMATX(I,IS1)
570      SMATX(I,OS2)=0.
      N=JSTRM(22)
      GO TO 600
C
C**********      CHECK EFFLUENT STANDARDS ON BOD, TSS, NH3, NO3, AND P
C
600      IF(J.NE.JSTRM(2))RETURN
      JLEFF=JSTRM(15)
      IF(SMATX(8,JLEFF)+SMATX(17,JLEFF).GT.EFFSTD(1))GO TO 700
      IF(SMATX(10,JLEFF).GT.EFFSTD(2))GO TO 700
      IF(SMATX(5,JLEFF)+SMATX(18,JLEFF).GT.EFFSTD(3))GO TO 700
      IF(SMATX(19,JLEFF).GT.EFFSTD(4))GO TO 700
      IF(SMATX(14,JLEFF).GT.EFFSTD(5))GO TO 700
      RETURN
C
C**********      INFEASIBLE OPTION
C
700      DO 710 K=1,10
710      C(J,K)=100.E20
      C(J,5)=0.
      DO 720 I=1,20
      SMATX(I,OS1)=SMATX(I,IS1)
720      SMATX(I,OS2)=0.
      RETURN
      END
```

```
C
C
C****************************************************************
C                                                              *
C            PENALTY SUBROUTINE                                *
C                                                              *
C****************************************************************
C
      SUBROUTINE PNALTY(V1)
C
      COMMON SMATX(20,45),DUMMY1(2000),IDUMMY(58),
     2         DUMMY2(28)
      COMMON/PROC/ ID(225),JSTRM(22),JSIDE(20),P(20,10),IZOPT(20),
     2               PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      DIMENSION TRECYC(20),DV(20,10),VR1(10),VO(10),DVSUM(10)
     2            ,V1(10),RECYC(20)
C
      DO 5 K=1,10
5      DVSUM(K)=0.
      DO 10 I=2,20
      RECYC(I)=0.
      DO 10 K=1,10
      P(I,K)=0.
10      DV(I,K)=0.
C
C**********      EVALUATE SYSTEM PERFORMANCE WITHOUT RETURNING SLUDGE
C            TREATMENT RECYCLE FLOWS, THEN MIX RECYCLE FLOWS TOGETHER.
C
      CALL SYSTEM(WV,VO,RECYC)
      J=JSTRM(17)
      J1=JSTRM(3)
      J2=JSTRM(6)
      J3=JSTRM(20)
      CALL SMIX(J,J1,J2,J3)
      DO 15 I=2,20
15      TRECYC(I)=SMATX(I,J)
C
C**********      EVALUATE CHANGE IN EACH SELECTION CRITERION AS EACH
C            RECYCLE STREAM COMPONENT IS RETURNED FOR TREATMENT
C
      Q1=TRECYC(2)
      Q2=.001*PINFLO(2)
      IF(TRECYC(2).LT.Q2)RETURN
      DO 200 I=2,18
      GO TO (200,20,200,40,50,60,70,80,200,200,200,120,200,140,200,
     2         140,170,190), I
      GO TO 200
C
C            Q
C
20      RECYC(2)=TRECYC(2)
      GO TO 180
C
C            SNBC
C
40      RECYC(2)=Q2
```

```
      RECYC(4)=TRECYC(4)*Q1/Q2
      RECYC(3)=RECYC(4)
      RECYC(9)=RECYC(4)
      RECYC(10)=RECYC(4)
      GO TO 180
C
C           SON
C
50      RECYC(2)=Q2
      RECYC(5)=TRECYC(5)*Q1/Q2
      RECYC(9)=RECYC(5)
      RECYC(10)=RECYC(5)
      GO TO 180
C
C           SOP
C
60      RECYC(2)=Q2
      RECYC(6)=TRECYC(6)*Q1/Q2
      RECYC(9)=RECYC(6)
      RECYC(10)=RECYC(6)
      GO TO 180
C
C           SFM
C
70      RECYC(2)=Q2
      RECYC(7)=TRECYC(7)*Q1/Q2
      RECYC(10)=RECYC(7)
      GO TO 180
C
C           SBOD
C
80      RECYC(2)=Q2
      RECYC(8)=TRECYC(8)*Q1/Q2
      RECYC(3)=RECYC(8)/1.87
      RECYC(9)=RECYC(8)/1.87
      RECYC(10)=RECYC(8)/1.87
      GO TO 180
C
C           OTHER VSS (NOT SOC, SON, OR SOP)
C
90      RECYC(2)=Q2
      RECYC(9)=(TRECYC(9)-TRECYC(3)-TRECYC(5)-TRECYC(6))*Q1/Q2
      RECYC(10)=RECYC(9)
      GO TO 180
C
C           DNBC
C
120     RECYC(2)=Q2
      RECYC(12)=TRECYC(12)*Q1/Q2
      RECYC(11)=RECYC(12)
      GO TO 180
C
C           OTHER DN (NOT NH3 OR NO3)
C
130     RECYC(2)=Q2
      RECYC(13)=(TRECYC(13)-TRECYC(18)-TRECYC(19))*Q1/Q2
      GO TO 180
C
C            DP OR ALK
C
140      RECYC(2)=Q2
      RECYC(I)=TRECYC(I)*Q1/Q2
      GO TO 180
C
C            DBOD
C
170      RECYC(2)=Q2
      RECYC(17)=TRECYC(17)*Q1/Q2
      RECYC(11)=RECYC(17)/1.87
      GO TO 180
C
C            NH3
C
190      RECYC(2)=Q2
      RECYC(18)=TRECYC(18)*Q1/Q2
      RECYC(13)=RECYC(18)
C
C
180      DO 185 II=2,20
185      IF(RECYC(II).LT.0.)RECYC(II)=0.
         CALL SYSTEM(WV,VR1,RECYC)
      DO 186 K=1,10
      DV(I,K)=VR1(K)-V0(K)
186      DVSUM(K)=DVSUM(K)+DV(I,K)
194      DO 195 II=2,20
195      RECYC(II)=0.
200      CONTINUE
C
C
      DO 210 I=1,20
210      RECYC(I)=TRECYC(I)
C
C            PENALTY = MARGINAL CHANGE IN CRITERION / MASS FLOW *
C                                  ADJUSTMENT FACTOR
C            ADJUSTMENT FACTOR = (CRITERION W/ RECYCLE - CRITERION W/O
C                                  RECYCLE) / SUM OF MARGINAL CHANGES
C
      DO 230 K=1,10
      IF(DVSUM(K).EQ.0.)GO TO 230
      DEL=(V1(K)-V0(K))/DVSUM(K)
      P(2,K)=DV(2,K)*DEL/TRECYC(2)
      DO 220 I=3,20
      IF(TRECYC(I).EQ.0.)GO TO 220
      P(I,K)=DV(I,K)*DEL/(TRECYC(2)*TRECYC(I))
220      CONTINUE
C
C            CORRECT COMPUTED PENALTIES FOR OTHER VSS AND DN
C
      TEMP=TRECYC(9)-TRECYC(3)-TRECYC(5)-TRECYC(6)
      IF(TEMP.LE.0.)GO TO 225
      P(9,K)=P(9,K)*TRECYC(9)/TEMP
225      TEMP=TRECYC(13)-TRECYC(18)-TRECYC(19)
```

```
      IF(TEMP.LE.0.)GO TO 230
      P(13,K)=P(13,K)*TRECYC(13)/TEMP
 230     CONTINUE
      RETURN
      END
```

```
C
C
C************************************************************
C                                                           *
C           STREAM MIXING SUBROUTINE                        *
C                                                           *
C************************************************************
C
       SUBROUTINE SMIX(J,J1,J2,J3)
C
      COMMON SMATX(20,45),DUMMY1(2000),IDUMMY(58),
     2        DUMMY2(28)
      COMMON/PROC/ ID(223),NTPS,NTPU,JSTRM(22),JSIDE(20),P(20,10),
     2             IZOPT(20),DUMMY(40),ISC(45),FPS(45)
C
      ISC(J)=1
      TEMP1=0.
      TEMP3=0.
C
C******      ONLY MIX THOSE STREAMS WHOSE DESTINATION IS STAGE J3
      DO 10 JT=J1,J2
      IF (JSIDE(JT) .NE. J3) GO TO 10
      JJ=JT+NTPS
        TEMP1=TEMP1+SMATX(2,JJ)
      TEMP3=TEMP3+FPS(JJ)*SMATX(2,JJ)*SMATX(10,JJ)
10      CONTINUE
      IF(TEMP1.EQ.0.)GO TO 50
      DO 30 I=3,20
      TEMP2=0.
      DO 20 JT=J1,J2
      IF (JSIDE(JT) .NE. J3) GO TO 20
        TEMP2=TEMP2+SMATX(2,JT+NTPS)*SMATX(I,JT+NTPS)
20      CONTINUE
30      SMATX(I,J)=TEMP2/TEMP1
40      SMATX(2,J)=TEMP1
      FPS(J)=TEMP3/SMATX(2,J)/SMATX(10,J)
      RETURN
50      DO 60 I=2,20
60      SMATX(I,J)=0.
      FPS(J)=0.
      RETURN
      END
```

```
C
C
C*****************************************************************
C                                                                *
C           INFLUENT STREAM SUBROUTINE                           *
C                                                                *
C*****************************************************************
C
      SUBROUTINE STRMIN(J,RECYC)
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DUMMY1(2000),IP(50),
     2       INP,IO,IS1,IS2,OS1,OS2,N,IAERF,DUMMY2(28)
      COMMON/PROC/IDUM1(220),NWPS,NPSPS,NSSPS,NTPS,NTPU,
     2             JSTRM(22),JSIDE(20),P(20,10),IZOPT(20),
     3             PINFLO(20),EFFSTD(20),ISC(45),FPS(45)
      DIMENSION RECYC(20)
C
      IF (J .EQ. JSTRM(20)) GO TO 10
      IF (J .EQ. JSTRM(3 )) GO TO 30
      IF (J .EQ. JSTRM(5 )) GO TO 40
      GO TO 60
C
C**********      J = RECYCLE RETURN POINT. MIX INFLUENT AND SLUDGE
C           TREATMENT RECYCLE STREAMS.
C
10      IF (RECYC(2) .EQ. 0.) GO TO 80
      TEMP1=SMATX(2,J)+RECYC(2)
      DO 20 I=3,20
      TEMP2=SMATX(2,J)*SMATX(I,J)+RECYC(2)*RECYC(1)
20      SMATX(I,J)=TEMP2/TEMP1
      SMATX(2,J)=TEMP1
      SMATX(20,J)=0.
      GO TO 80
C
C**********      J = START OF SECONDARY SLUDGE TRAIN. MIX ALL SECONDARY
C           SLUDGES TOGETHER.
C
30      J1=JSTRM(1)
      J2=JSTRM(2)
      CALL SMIX(J,J1,J2,J)
      GO TO 80
C
C**********      J = START OF PRIMARY SLUDGE TRAIN. MIX ALL PRIMARY
C           SLUDGES TOGETHER.
C
40      J1=JSTRM(1)
      J2=JSTRM(2)
      CALL SMIX(J,J1,J2,J)
C
C**********      LOCATE STAGE WHERE SECONDARY AND PRIMARY SLUDGES
C           ARE MIXED TOGETHER
C
      JSTRM(21)=JSTRM(5)
      DO 50 JT=1,NSSPS
      IF (IP(IZOPT(JT+NWPS)) .NE. 0) JSTRM(21)=JSTRM(5)+JT
```

```
50        CONTINUE
60        IF (J .NE. JSTRM(21)) RETURN
C
C***********      J = MIXING POINT OF PRIMARY AND SECONDARY SLUDGES
C
      JT=JSTRM(16)
      TEMP1=SMATX(2,JT)+SMATX(2,J)
      TEMP3=SMATX(2,J)*SMATX(10,J)
      IF (TEMP1 .EQ. 0.) GO TO 90
      DO 70 I=3,20
      TEMP2=SMATX(2,JT)*SMATX(I,JT)+SMATX(2,J)*SMATX(I,J)
70        SMATX(I,J)=TEMP2/TEMP1
      SMATX(2,J)=TEMP1
      FPS(J)=(FPS(J)*TEMP3+FPS(JT)*SMATX(2,JT)*SMATX(10,JT))/
     2          SMATX(2,J)/SMATX(10,J)
      IF (FPS(J) .LT. 1.) ISC(J)=10*ISC(J)+ISC(JSTRM(16))
      IF (FPS(J) .EQ. 0.) ISC(J)=ISC(JSTRM(16))
80        RETURN
90        DO 100 I=2,20
100         SMATX(I,J)=0.
      FPS(J)=0.
      RETURN
      END
```

```
C
C***********************************************************************
C                                                                      *
C           UNIT PROCESS NUMBER 1                                      *
C                                                                      *
C              PRELIMINARY TREATMENT                                   *
C                                                                      *
C***********************************************************************
C
      SUBROUTINE PREL
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
      IPREL=DMATX(1,N)
      X=ALOG(SMATX(2,IS1)*DMATX(16,N))
      IF(IPREL) 30,20,30
   20 CCOST(1)=EXP(2.566569+.619151*X)*1000.*CCI*RATIC
      GO TO 40
   30 CCOST(1)=EXP(3.259716+.619151*X)*1000.*CCI*RATIC
   40 X=ALOG(SMATX(2,IS1))
      OHRS=EXP(6.398716+.230956*X+.164959*X**2-.014601*X**3)
      XMHRS=EXP(5.846098+.206513*X+.068842*X**2+.023824*X**3-
     . .004410*X**4)
      TMSU=EXP(7.235657+.399935*X-.224979*X**2+.110099*X**3-
     . .011026*X**4)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      EER=EXP(2.64866+.532611*X-.034378*X**2+.007274*X**3)
      EER=EER+EXP(.47668+.256486*X-.051504*X**2+.02465*X**3)
      EER=EER+DMATX(1,N)*3.01*EXP(.249*X)
      RETURN
      END
```

```
C
C*******************************************************************
C                                                                  *
C             UNIT PROCESS NUMBER 2                                *
C                                                                  *
C             PRIMARY SEDIMENTATION                                *
C                                                                  *
C*******************************************************************
C
      SUBROUTINE PRSET
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      XRSS=DMATX(2,N)*1.E4/SMATX(10,IS1)
      HPWK=DMATX(3,N)
C
C  COMPUTE COMPOSITION OF EFFLUENT AND SLUDGE STREAMS
      SMATX(2,OS2)=DMATX(1,N)*SMATX(2,IS1)/XRSS
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
      TEMP1=(1.-DMATX(1,N))*SMATX(2,IS1)/SMATX(2,OS1)
      TEMP2=DMATX(1,N)*SMATX(2,IS1)/SMATX(2,OS2)
      DO 10 I=3,10
      SMATX(I,OS1)=TEMP1*SMATX(I,IS1)
   10 SMATX(I,OS2)=TEMP2*SMATX(I,IS1)
      SMATX(20,OS1)=TEMP1*SMATX(20,IS1)
      SMATX(20,OS2)=TEMP2*SMATX(20,IS1)
      DO 20 I=11,19
      SMATX(I,OS2)=SMATX(I,IS1)
   20 SMATX(I,OS1)=SMATX(I,OS2)
C
C  DETERMINE OVERFLOW RATE AND SETTLER SIZE
      GPS=-2780.*ALOG(DMATX(1,N))-551.7
      APS=SMATX(2,IS1)*1000./GPS*DMATX(16,N)
C
C  COMPUTE SETTLER COSTS
      X=ALOG(APS)
      CCOST(1)=EXP(3.716354+.389861*X+.084560*X**2
     .          -.004718*X**3)*1000.*CCI*RATIO
      X=ALOG(APS/DMATX(16,N))
      OHRS=EXP(5.846565+.254813*X+.113703*X**2-.010942*X**3)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2-.011672*X**3)
      TMSU=EXP(5.669881+.750799*X)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)
     .          /SMATX(2,1)/3650.
      PGPM=SMATX(2,OS2)*116666.7/HPWK*DMATX(15,N)
      X=ALOG(PGPM)
      CCOST(2)=EXP(2.237330+.207628*X+.026479*X**2)*1000.
     2          *CCI*RATIO
      X=ALOG(PGPM/DMATX(15,N))
      OHRS=EXP(4.945153+.419391*X)
      XMHRS=EXP(3.993365+.444966*X)
      TMSU=EXP(4.433129+.642272*X)
      COSTO(2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)
     *          /SMATX(2,1)/3650.
      OMATX(1,N)=GPS
      OMATX(2,N)=APS
      OMATX(3,N)=PGPM
C
C  COMPUTE ENERGY USEAGE
      X=ALOG(APS/DMATX(16,N))
      EER=EXP(2.92248+.396798*X+.062424*X**2)
      X=ALOG(SMATX(2,IS1))
      EER=EER+EXP(1.70697+.293587*X+.075918*X**2-
     2               .002995*X**3)
      COSTO(3)=EER*CKWH/SMATX(2,1)/10.
      RETURN
      END
```

```
C
C***********************************************************************
C                                                                      *
C             UNIT PROCESS NUMBER 3                                    *
C                                                                      *
C          ACTIVATED SLUDGE - FINAL SETTLER                            *
C                                                                      *
C***********************************************************************
C
      SUBROUTINE AERFS
C
      REAL MLSS,MLVSS,MLISS,MLASS,MLRSS
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2          INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3          ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     4          CF,EER,EEP,ALAND
C
      IAERF=0
      BODLIM=DMATX(1,N)
      TSSLIM=DMATX(2,N)
      MLVSS=DMATX(3,N)
      RTURN=DMATX(4,N)
      CS    =DMATX(5,N)
      CY    =DMATX(6,N)
      CK    =DMATX(7,N)
      CB    =DMATX(8,N)
      CKN   =DMATX(9,N)
      AEFF  =DMATX(10,N)
      GSS   =DMATX(11,N)
      HEAD  =DMATX(12,N)
C
C       MLASS = MIXED LIQUOR ACTIVE BIOMASS
C       MLRSS = MIXED LIQUOR REFRACTORY VOLATILES
C       MLISS = MIXED LIQUOR INERTS
C       BOD2  = SOLUBLE BOD IN AERATOR EFFLUENT
C
C    COMPUTE INFLUENT CONC. OF BOD AND SOLIDS
      BOD1=SMATX(8,IS1)+SMATX(17,IS1)
      IF (BOD1 .LE. BODLIM) GO TO 1000
      MLASS=SMATX(20,IS1)
      MLRSS=SMATX(4,IS1)*SMATX(9,IS1)/SMATX(3,IS1)
      MLISS=SMATX(7,IS1)
C
C    USE METHOD OF FALSE POSITION TO FIND THE SRT AND BOD2 THAT
C    WILL RESULT IN BODEFF = BODLIM.
C    STEP1 - FIND AN SRT THAT GIVES BODEFF .GT. BODLIM
      SRT=3.
      BOD2=CS*(1.+CB*SRT)/(SRT*(CY*CK-CB)-1.)
      INDEX=1
      GO TO 25
101       X1=SRT
      Y1=BODEFF-BODLIM
      IF(Y1.LE.0.)GO TO 30
C
C    STEP 2 - FIND AN SRT THAT GIVES BODEFF .LT. BODLIM
```

```
      SRT=6.
5      BOD2=CS*(1.+CB*SRT)/(SRT*(CY*CK-CB)-1.)
      INDEX=2
      GO TO 25
102      X2=SRT
      Y2=BODEFF-BODLIM
      IF(Y2.LE.0.)GO TO 15
      SRT=SRT+3.
      IF(SRT.GT.21.)GO TO 1000
      GO TO 5
C
C   STEP 3 - INTERPOLATE BETWEEN X1 AND X2 TO ESTIMATE A NEW SRT
15       SRT=(X2*Y1-X1*Y2)/(Y1-Y2)
      BOD2=CS*(1.+CB*SRT)/(SRT*(CY*CK-CB)-1.)
      INDEX=3
      GO TO 25
103      IF(ABS(BODEFF-BODLIM).LE.0.001*BODLIM)GO TO 30
C
C   STEP 4 - DISCARD OLD POINT THAT IS ON SAME SIDE OF BODLIM AS IS THE
C            CURRENT BODEFF AND RETURN TO STEP 3
      IF(Y1*(BODEFF-BODLIM).LE.0.)GO TO 20
      Y1=Y2
      X1=X2
20       Y2=BODEFF-BODLIM
      X2=SRT
      GO TO 15
C
C   COMPUTE HRT, SETTLER EFFICIENCY, AND BODEFF
25       HRT=SRT/MLVSS*(MLRSS+CY*(BOD1-BOD2)/(1.+CB*SRT)*(1.+.2*CB*SRT))
      XRSS=TSSLIM/(MLVSS+MLISS*SRT/HRT)
      BODEFF=BOD2+.97*.8*XRSS*SRT/HRT*CY*(BOD1-BOD2)/(1.+CB*SRT)
      GO TO (101,102,103), INDEX
C
C   COMPUTE CONC. OF SOLIDS IN AERATOR
30       MLASS=SRT/HRT*CY*(BOD1-BOD2)/(1.+CB*SRT)
      MLRSS=.2*CB*MLASS*SRT+SRT/HRT*MLRSS
      MLISS=SRT/HRT*MLISS
      MLSS=MLVSS+MLISS
C
C   FIND WASTE SLUDGE SOLIDS CONC. AND FLOW RATE
      SMATX(10,OS1)=TSSLIM
      SMATX(10,OS2)=MLSS/RTURN*(1.+RTURN-HRT/SRT)
      SMATX(2,OS2)=SMATX(2,IS1)*(MLSS*(1.+RTURN)-SMATX(10,OS1)-
     2                SMATX(10,OS2)*RTURN)/(SMATX(10,OS2)-SMATX(10,OS1))
      SMATX(2,OS1)=SMATX(2,IS1)-SMATX(2,OS2)
C
C   COMPUTE CONC. OF SOLIDS SPECIES IN OVERFLOW
      SMATX(4,OS1)=XRSS*(.2*CB*MLASS*SRT/2.46+SMATX(4,IS1)*SRT/HRT)
      SMATX(4,OS1)=SMATX(4,OS1)+XRSS*.2*MLASS/2.46
      SMATX(3,OS1)=SMATX(4,OS1)+XRSS*.8*MLASS/2.46
      SMATX(5,OS1)=XRSS*(.12*MLASS+.06*MLRSS)
      SMATX(6,OS1)=XRSS*.025*MLASS
      SMATX(7,OS1)=XRSS*MLISS
      SMATX(8,OS1)=BODEFF-BOD2
      SMATX(9,OS1)=XRSS*MLVSS
      SMATX(20,OS1)=XRSS*MLASS
```

```
C
C   COMPUTE CONC. OF SOLID SPECIES IN UNDERFLOW
      R=SMATX(10,OS2)/SMATX(10,OS1)
      DO 40 I=3,9
40       SMATX(I,OS2)=SMATX(I,OS1)*R
      SMATX(20,OS2)=SMATX(20,OS1)*R
C
C   COMPUTE DISSOLVED C, N, P, AND FIXED MATTER
      SMATX(11,OS1)=SMATX(12,IS1)+BOD2/BOD1*(SMATX(11,IS1)-
     2  SMATX(12,IS1))
      SMATX(12,OS1)=SMATX(12,IS1)
      SMATX(13,OS1)=SMATX(13,IS1)+SMATX(5,IS1)-SMATX(5,OS1)*SMATX(2,OS1)
     2 /SMATX(2,IS1)-SMATX(5,OS2)*SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(14,OS1)=SMATX(14,IS1)+SMATX(6,IS1)-SMATX(6,OS1)*SMATX(2,OS1)
     2 /SMATX(2,IS1)-SMATX(6,OS2)*SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(15,OS1)=SMATX(15,IS1)
C
C   CHECK FOR NITRIFICATION (SRT .GE. 5 DAYS)
      IF(SRT.LT.5.)GO TO 50
      IF(SRT*.05*CKN.LE.1.)GO TO 50
      SMATX(18,OS1)=1.*(1./((SRT*.05*CKN)-1.))
      SMATX(19,OS1)=SMATX(13,OS1)-SMATX(18,OS1)
      GO TO 60
50       SMATX(19,OS1)=SMATX(19,IS1)
      SMATX(18,OS1)=SMATX(13,OS1)-SMATX(19,OS1)
C
C   ADJUST ALKALINITY AND DISSOLVED BOD
60       SMATX(16,OS1)=SMATX(16,IS1)-7.14*(SMATX(19,OS1)-SMATX(19,IS1))
      SMATX(17,OS1)=BOD2
      DO 70 I=11,19
70       SMATX(I,OS2)=SMATX(I,OS1)
C
C   SIZE THE AERATION TANK
      VAER=HRT*SMATX(2,IS1)*DMATX(16,N)
      X=ALOG(VAER*1000./7.48)
      CCOST(1)=EXP(2.414380+.175682*X+.084742*X**2-.002670*X**3)*1000.
     2            *CCI*RATIO
      COSTO(1)=0.
C
C   COMPUTE AIR REQUIREMENTS
      ARCFD=(1.5-1.42*CY)*SMATX(2,IS1)*(BOD1-BOD2)*8.33
      ARCFD=ARCFD+1.42*CB*.8*MLASS*VAER*8.33
      ARCFD=ARCFD+4.6*(SMATX(19,OS1)-SMATX(19,IS1))*SMATX(2,IS1)*8.33
      IF (AEFF .GE. 1.0) GO TO 71
C  DIFFUSED AERATION
      ARCFD=ARCFD/AEFF/.232/.075
      BSIZE=ARCFD/1440.*DMATX(15,N)
      CFPGL=ARCFD/1.E6/SMATX(2,IS1)
      X=ALOG(BSIZE/1000.)
      CCOST(2)=EXP(4.145454+.633339*X+.031939*X**2-.002419*X**3)*1000.
     2            *CCI*RATIO
      X=ALOG(BSIZE/1000./DMATX(15,N))
      OHRS=EXP(6.900586+.323725*X+.059093*X**2-.004926*X**3)
      XMHRS=EXP(6.169937+.294853*X+.175999*X**2-.040947*X**3+
     2            .003300*X**4)
      HP=BSIZE/DMATX(15,N)*8.1*144./(33000.*.8)
      GO TO 73
C  MECHANICAL AERATION
71      HP=ARCFD/AEFF/24.
      BSIZE=HP*DMATX(15,N)
      ARCFD=HP
      CFPGL=0.
      CCOST(2)=1000.*BSIZE**.8825*CCI*RATIO
      OHRS=150.*HP**.49
      XMHRS=53.*HP**.568
73      SCOST=2000.*SMATX(2,1)**.477
      XKW=.8*HP
      XKWPY=XKW*24.*365.
      ECOST=XKWPY*CKWH
      TMSU=ECOST+SCOST*WPI
      COSTO(2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
C
C   COMPUTE RETURN SLUDGE PUMPING REQUIREMENTS
      QR=RTURN*SMATX(2,IS1)*DMATX(14,N)
      X=ALOG(QR)
      CCOST(3)=EXP(3.481553+.377485*X+.093349*X**2-.006222*X**3)*1000.
     2        *CCI*RATIO
      X=ALOG(QR/DMATX(14,N))
      OHRS=EXP(6.097269+.253066*X-.193659*X**2+.078201*X**3-
     2        .006680*X**4)
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2)
      IF (QR-1.44) 72,74,74
72      PEFF=.7
      GO TO 80
74      IF (QR-10.08) 76,78,78
76      PEFF=.74
      GO TO 80
78      PEFF=.83
80      YKWPY=QR*1.E6*HEAD/1440./3690./PEFF/.9*.7457*24.*365.
      ECOST=YKWPY*CKWH
      SCOST=EXP(5.051743+.301610*X+.197183*X**2-.017962*X**3)
      TMSU=ECOST+SCOST*WPI
      COSTO(3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
C
C   COMPUTE FINAL SETTLER REQUIREMENTS
C   (THICKENING CRITERION BASED ON SETTLING CURVE PARAMETERS
C    VEL.=.04*CONC.**.6 )
      AFS=SMATX(2,OS1)*1000./GSS*DMATX(13,N)
      AFS2=.04*SMATX(2,IS1)*(1.+RTURN)*MLSS/1000.*(SMATX(10,OS2)/1000.)
     2  **.6
      IF(AFS2.GT.AFS)AFS=AFS2
      X=ALOG(AFS)
      CCOST(4)=EXP(3.716354+.389861*X+.084560*X**2-.004718*X**3)*1000.
     2        *CCI*RATIO
      X=ALOG(AFS/DMATX(13,N))
      OHRS=EXP(5.846565+.254813*X+.113703*X**2-.010942*X**3)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2-.011672*X**3)
      TMSU=EXP(5.669881+.750799*X)
      COSTO(4)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C   FILL IN OUTPUT MATRIX VALUES
      OMATX(1,N) =BOD2
      OMATX(2,N) =SRT
      OMATX(3,N) =VAER/SMATX(2,IS1)*24.
      OMATX(4,N) =VAER
      OMATX(5,N) =AFS
      OMATX(6,N) =XRSS
      OMATX(7,N) =MLASS
      OMATX(8,N) =MLRSS
      OMATX(9,N) =MLISS
      OMATX(10,N)=ARCFD
      OMATX(11,N)=BSIZE
      OMATX(12,N)=CFPGL
      OMATX(13,N)=QR
C
C   COMPUTE ENERGY REQUIREMENTS
      EER=XKWPY/365.+YKWPY/365.
      EER=EER+EXP(2.8248+.30093*X+.022308*X**2+.0035144*X**3)
      RETURN
1000       IAERF=1
      RETURN
      END
```

```
C
C*****************************************************************
C                                                                *
C           UNIT PROCESS NUMBER 4                                *
C                                                                *
C              ANAEROBIC DIGESTION                               *
C                                                                *
C*****************************************************************
C
      SUBROUTINE DIG
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DIG12=SMATX(3,IS1)-SMATX(4,IS1)+SMATX(11,IS1)-SMATX(12,IS1)
      TD=DMATX(1,N)
C
C  COMPUTE COMPOSITION OF EFFLUENT STREAMS
      SMATX(2,OS1)=SMATX(2,IS1)
      SMATX(3,OS1)=(1.-DMATX(9,N))*SMATX(3,IS1)
      DIG13=(SMATX(3,OS1)-SMATX(4,IS1))/.75
      SMATX(4,OS1)=SMATX(4,IS1)
      SMATX(5,OS1)=(1.-.65*DMATX(9,N))*SMATX(5,IS1)
      SMATX(6,OS1)=(1.-DMATX(9,N))*SMATX(6,IS1)
      SMATX(7,OS1)=SMATX(7,IS1)+.25*DMATX(9,N)*SMATX(9,IS1)
      SMATX(9,OS1)=(1.-DMATX(9,N))*SMATX(9,IS1)
      SMATX(10,OS1)=SMATX(7,OS1)+SMATX(9,OS1)
      SMATX(11,OS1)=SMATX(12,IS1)+.25*DIG13
      SMATX(12,OS1)=SMATX(12,IS1)
      SMATX(13,OS1)=SMATX(13,IS1)+.65*DMATX(9,N)*SMATX(5,IS1)
      SMATX(14,OS1)=SMATX(14,IS1)+DMATX(9,N)*SMATX(6,IS1)
      SMATX(15,OS1)=SMATX(15,IS1)
      SMATX(16,OS1)=SMATX(16,IS1)+(SMATX(13,OS1)-SMATX(13,IS1))*3.57
      SMATX(18,OS1)=SMATX(18,IS1)+SMATX(13,OS1)-SMATX(13,IS1)
      SMATX(19,OS1)=0.
      SMATX(8,OS1)=SMATX(8,IS1)*(SMATX(3,OS1)-SMATX(4,OS1))/
     2              (SMATX(3,IS1)-SMATX(4,IS1))
      SMATX(17,OS1)=SMATX(17,IS1)*(SMATX(11,OS1)-SMATX(12,OS1))/
     2               (SMATX(11,IS1)-SMATX(12,IS1))
      SMATX(20,OS1)=SMATX(20,IS1)+.75*DIG13/(SMATX(3,IS1)-SMATX(4,IS1))
C
C  COMPUTE GAS PRODUCTION
      CH4=163.85/249.9*DMATX(9,N)*SMATX(2,IS1)*DMATX(10,N)*SMATX(9,IS1)*
     2     8.33
      CO2=CH4*(249.9/163.85-1.)
C
C  COMPUTE DIGESTER COSTS
      VDIG=SMATX(2,IS1)*TD*1000./7.48*DMATX(16,N)
      X=ALOG(VDIG)
      IF(VDIG-20.) 22,25,25
22    CCOST(1)=EXP(4.594215+.127244*X-.004001*X**2)*1000.*CCI*RATIO
      GO TO 28
   25 CCOST(1)=EXP(7.679634-1.949689*X+.402610*X**2-.018211*X**3)*
```

```
     . 1000.*CCI*RATIO
   28 X=ALOG(VDIG/DMATX(16,N))
      IF(VDIG-20.) 30,40,40
   30 OHRS=EXP(6.163803+.166305*X-.012470*X**2)
      XMHRS=EXP(5.726981+.113674*X)
      TMSU=EXP(6.531623+.198417*X+.021660*X**2)
      GO TO 50
   40 OHRS=EXP(9.129250-1.816736*X+.373282*X**2-.017290*X**3)
      XMHRS=EXP(8.566752-1.768137*X+.363173*X**2-.016620*X**3)
      TMSU=EXP(8.702803-1.182711*X+.282691*X**2-.013672*X**3)
   50 COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      OMATX(1,N)=DMATX(9,N)
      OMATX(2,N)=DMATX(10,N)
      OMATX(3,N)=VDIG
      OMATX(4,N)=CH4
      OMATX(5,N)=CO2
C
C  COMPUTE DIGESTER MIXING AND HEATING ENERGY REQUIREMENTS
      E1=9.589*VDIG/DMATX(16,N)
      TDIG=1.8*DMATX(2,N)+32.
      CAP=SMATX(2,IS1)*8.33*1.E6*(TDIG-60.)
      XX=ALOG(CAP/1000./24.)
      E2=.75*24.*.7457*EXP(2.00069-1.02649*XX+.127492*XX**2)
      E3=CAP/.75
      E4=VDIG/DMATX(16,N)*62500.*DMATX(3,N)/.75
      ENERGY=600.*(CH4+CO2)
      EER=E1+E2+(E3+E4)*.000293*CF
      EEP=0.
      IF(DMATX(4,N).EQ.0.) GO TO 60
C
C  GAS USED ONLY FOR DIGESTER HEATING
      EEP=AMIN1(ENERGY,E3+E4)
      EEP=EEP*.000293*CF
      RETURN
60       IF (DMATX(5,N) .EQ. 0.) RETURN
C
C  GAS USED TO RUN IC ENGINE
      EEP=ENERGY*DMATX(6,N)*.000293
      TEMP=AMIN1(ENERGY*DMATX(7,N),E3+E4)
      EEP=EEP+TEMP*.000293*CF
C
C  COMPUTE COST OF GAS UTILIZATION
      CCOST(2)=1.506/2.558*73000.*SMATX(2,1)**.7558*CCI*RATIO
      OHRS=105.5*SMATX(2,1)**.88
      TMSU=1.122/1.789*1054.*SMATX(2,1)**.856
      UEER=31000.*SMATX(2,1)**.818
      UHER=222.*SMATX(2,1)
      UECOST=UEER*CKWH
      UFCOST=UHER*DMATX(8,N)
      COSTO(2)=(OHRS*DHR*(1.+PCT)+TMSU*WPI+UECOST+
     2              UFCOST)/SMATX(2,1)/3650.
      EER=EER+UEER/365.+UHER*293.*CF/365.
      RETURN
      END
```

```
C
C*************************************************************
C                                                            *
C             UNIT PROCESS NUMBER 7                          *
C                                                            *
C                  VACUUM FILTRATION                         *
C                                                            *
C*************************************************************
C
      SUBROUTINE VACF
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
      FECL3=DMATX(8,N)
      CAO=DMATX(9,N)
      CFECL=DMATX(3,N)
      CCAO=DMATX(4,N)
      DPOLY=DMATX(10,N)
      CPOLY=DMATX(5,N)
      SAVE1=SMATX(7,IS1)
      SAVE2=SMATX(10,IS1)
      SMATX(7,IS1)=SMATX(7,IS1)+(FECL3+CAO+DPOLY)*SMATX(10,IS1)/2000.
      SMATX(10,IS1)=SMATX(10,IS1)+(FECL3+CAO+DPOLY)*SMATX(10,IS1)/2000.
      SMATX(10,OS2)=DMATX(2,N)
C
C  COMPUTE MOISTURE CONTENT OF SLUDGE CAKE AND PERFORM MASS
C  BALANCES AROUND UNIT
      WP=88./(SMATX(10,IS1)/10000.)**.123
      SMATX(10,OS1)=(100.-WP)*10000.
      SMATX(2,OS1)=(SMATX(2,IS1)*SMATX(10,IS1))/(SMATX(10,OS1)-
     . SMATX(10,OS2))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
      TEMP2=SMATX(10,OS1)/SMATX(10,IS1)
      TEMP3=SMATX(10,OS2)/SMATX(10,IS1)
      DO 10 I=3,9
      SMATX(I,OS1)=TEMP2*SMATX(I,IS1)
   10 SMATX(I,OS2)=TEMP3*SMATX(I,IS1)
      DO 20 I=11,19
      SMATX(I,OS1)=SMATX(I,IS1)
20      SMATX(I,OS2)=SMATX(I,IS1)
      SMATX(20,OS1)=SMATX(20,IS1)*TEMP2
      SMATX(20,OS2)=SMATX(20,IS1)*TEMP3
C
C  DETERMINE FILTER AREA
      SF=SMATX(10,IS1)/10000.
      SC=100.-WP
      FVF=DMATX(7,N)/11.99/(1./SF-1./SC)
      AVF=SMATX(10,IS1)*SMATX(2,IS1)*58.31/FVF/DMATX(1,N)*DMATX(16,N)
C
C  COMPUTE FILTER COSTS
      IVACF=1.
      PSDD=SMATX(10,IS1)*SMATX(2,IS1)*8.33
      X=ALOG(AVF)
      CCOST(1)=EXP(3.288028+.194537*X+.038313*X**2)*1000.*CCI*RATIO
      X=ALOG(PSDD*365./2000.)
      IF(IVACF) 40,30,40
   30 OHRS=EXP(6.069419-.009894*X+.042699*X**2)
      GO TO 50
   40 OHRS=EXP(3.714368+.850848*X-.074615*X**2+.005085*X**3)
   50 XMHRS=EXP(4.306110-.093695*X+.047738*X**2)
      SUPP=EXP(-3.113515+.718466*X)*1000.
      CHEM=PSDD*365./2000.*(FECL3*CFECL+CAO*CCAO+DPOLY*CPOLY)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+SUPP*WPI+CHEM)/
     . SMATX(2,1)/3650.
      OMATX(1,N)=WP
      OMATX(2,N)=AVF
      OMATX(3,N)=PSDD
      OMATX(4,N)=DMATX(7,N)
      OMATX(5,N)=DMATX(8,N)
      OMATX(6,N)=DMATX(9,N)
      OMATX(7,N)=DMATX(10,N)
C
C  COMPUTE ENERGY USEAGE
      X=ALOG(AVF/DMATX(16,N))
      EER=EXP(3.21323+.378196*X+.036877*X**2)
      X=ALOG(SMATX(2,IS1)*SMATX(10,IS1)*8.33/2000.)
      EER=EER+EXP(2.3018+.36033*X+.089968*X**2-
     2                .0057516*X**3)
      COSTO(2)=EER*CKWH/SMATX(2,1)/10.
      SMATX(7,IS1)=SAVE1
      SMATX(10,IS1)=SAVE2
      RETURN
      END
```

```
C
C*********************************************************************
C                                                                    *
C            UNIT PROCESS NUMBER 8                                   *
C                                                                    *
C               GRAVITY THICKENING                                   *
C                                                                    *
C*********************************************************************
C
      SUBROUTINE THICK
C
      INTEGER OS1,OS2
      DIMENSION SMAT(20)
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DO 2 I=1,20
    2 SMAT(I)=0.
      IF(IS2) 7,7,4
    4 DO 6 I=1,20
    6 SMAT(I)=SMATX(I,IS2)
    7 SMATX(10,OS1)=DMATX(9,N)*1.E4
      IF (SMATX(10,OS1) .LE. SMATX(10,IS1)) GO TO 1000
C
C  PERFORM FLOW AND MASS BALANCES TO DETERMINE COMPOSITION
C  OF UNDERFLOW AND SUPERNATANT
      SMATX(2,OS1)=DMATX(1,N)*(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*
     . SMAT(10))/SMATX(10,OS1)
      TEMP=DMATX(4,N)/DMATX(2,N)*1000000./8.33
      IF(IS2) 9,8,9
    8 WRT=0.
      GO TO 10
    9 WRT=(SMATX(10,IS1)-TEMP)/(TEMP-SMAT(10))
      SMATX(2,IS2)=WRT*SMATX(2,IS1)
      SMAT(2)=SMATX(2,IS2)
   10 SMATX(2,OS2)=SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)
      TEMP=SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10)
      SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)
      TEMP=TEMP/(SMATX(2,IS1)+SMAT(2))
      TEMP1=SMATX(10,OS1)/TEMP
      TEMP2=SMATX(10,OS2)/TEMP
      DO 15 I=3,9
      TEMP3=(SMATX(2,IS1)*SMATX(I,IS1)+SMAT(2)*SMAT(I))/
     . (SMATX(2,IS1)+SMAT(2))
      SMATX(I,OS1)=TEMP1*TEMP3
   15 SMATX(I,OS2)=TEMP2*TEMP3
      TEMP3=(SMATX(2,IS1)*SMATX(20,IS1)+SMAT(2)*SMAT(20))/
     2        (SMATX(2,IS1)+SMAT(2))
      SMATX(20,OS1)=TEMP1*TEMP3
      SMATX(20,OS2)=TEMP2*TEMP3
      DO 20 I=11,19
      SMATX(I,OS1)=(SMATX(I,IS1)*SMATX(2,IS1)+SMAT(I)*SMAT(2))/
     . (SMATX(2,IS1)+SMAT(2))
   20 SMATX(I,OS2)=SMATX(I,OS1)
```

```
C
C  SIZE THICKENER AND COMPUTE COSTS
      ATH1=(SMATX(2,OS2)+SMATX(2,OS1))*1000000./DMATX(2,N)*DMATX(16,N)
      IF(IS2) 40,25,40
   25 ATH2=SMATX(2,IS1)*SMATX(10,IS1)*8.33/DMATX(10,N)*DMATX(16,N)
      IF(ATH1-ATH2) 30,40,40
   30 ATHM=ATH2
      GO TO 50
   40 ATHM=ATH1
   50 X=ALOG(ATHM/1000.)
      CCOST(1)=EXP(3.725902+.397690*X+.075742*X**2-.001977*X**3-
     . .000296*X**4)*1000.*CCI*RATIO
      X=ALOG(ATHM/1000./DMATX(16,N))
      IF(EXP(X)-1.) 60,70,70
   60 OHRS=350.
      XMHRS=190.
      TMSU=250.
      GO TO 80
   70 OHRS=EXP(5.846565+.254813*X+.113703*X**2-.010942*X**3)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2-.011672*X**3)
      TMSU=EXP(5.669881+.750799*X)
   80 COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      OMATX(1,N)=ATHM
      OMATX(2,N)=WRT
      OMATX(3,N)=DMATX(9,N)
      OMATX(4,N)=DMATX(10,N)
C
C  DETERMINE ENERGY USEAGE
      X=ALOG(ATHM/DMATX(16,N))
      EER=EXP(5.50543-1.59789*X+.206121*X**2-.005617*X**3)
      COSTO(2)=EER*CKWH/SMATX(2,1)/10.
      RETURN
1000      IAERF=1
      RETURN
      END
```

```
C
C*****************************************************************
C                                                               *
C          UNIT PROCESS NUMBER 9                                *
C                                                               *
C                 ELUTRIATION                                   *
C                                                               *
C*****************************************************************
C
      SUBROUTINE ELUT
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      SMATX(10,OS1)=DMATX(10,N)*1.E4
      IF (SMATX(10,OS1) .LE. SMATX(10,IS1)) GO TO 1000
      SAVE=SMATX(2,IS2)
C
C  PERFORM FLOW AND MASS BALANCES AROUND UNIT TO DETERMINE COMPOSITION
C  OF UNDERFLOW AND SUPERNATANT
      SMATX(2,IS2)=DMATX(9,N)*SMATX(2,IS1)
      AE1=(SMATX(2,IS1)+SMATX(2,IS2))*1000000./DMATX(2,N)
      AE2=SMATX(2,IS1)*SMATX(10,IS1)*8.33/DMATX(11,N)
      AE2=AE2+(SMATX(2,IS2)*SMATX(10,IS2)*8.33/DMATX(11,N))
C
C  DETERMINE REQUIRED SURFACE AREA
      IF(AE1-AE2) 20,20,10
   10 AE=AE1*DMATX(16,N)
      GO TO 30
   20 AE=AE2*DMATX(16,N)
   30 SMATX(2,OS1)=DMATX(1,N)*SMATX(2,IS1)*SMATX(10,IS1)/SMATX(10,OS1)
      SMATX(2,OS2)=SMATX(2,IS1)+SMATX(2,IS2)-SMATX(2,OS1)
      TEMP=SMATX(2,IS1)*SMATX(10,IS1)+SMATX(2,IS2)*SMATX(10,IS2)
      SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)
      TEMP=TEMP/(SMATX(2,IS1)+SMATX(2,IS2))
      TEMP1=SMATX(10,OS1)/TEMP
      TEMP2=SMATX(10,OS2)/TEMP
      DO 40 I=3,9
      TEMP3=(SMATX(2,IS1)*SMATX(I,IS1)+SMATX(2,IS2)*SMATX(I,IS2))/
     . (SMATX(2,IS1)+SMATX(2,IS2))
      SMATX(I,OS1)=TEMP1*TEMP3
   40 SMATX(I,OS2)=TEMP2*TEMP3
      TEMP3=(SMATX(2,IS1)*SMATX(20,IS1)+SMATX(2,IS2)*SMATX(20,IS2))/
     2        (SMATX(2,IS1)+SMATX(2,IS2))
      SMATX(20,OS1)=TEMP1*TEMP3
      SMATX(20,OS2)=TEMP2*TEMP3
      DO 50 I=11,19
      SMATX(I,OS1)=(SMATX(I,IS1)*SMATX(2,IS1)+SMATX(I,IS2)*SMATX(2,IS2))
     . /(SMATX(2,IS1)+SMATX(2,IS2))
   50 SMATX(I,OS2)=SMATX(I,OS1)
C
C  COMPUTE PROCESS COSTS
      X=ALOG(AE/1000.)
      CCOST(1)=EXP(3.725902+.397690*X+.075742*X**2-.001977*X**3-
     * .000296*X**4)*1000.*CCI*RATIO
      X=ALOG(AE/1000./DMATX(16,N))
      IF(EXP(X)-1.) 60,70,70
   60 OHRS=350.
      XMHRS=190.
      TMSU=250.
      GO TO 80
   70 OHRS=EXP(5.846565+.254813*X+.113703*X**2-.010942*X**3)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2-.011672*X**3)
      TMSU=EXP(5.669881+.750799*X)
   80 COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      OMATX(1,N)=AE
      OMATX(2,N)=DMATX(10,N)
      OMATX(3,N)=DMATX(11,N)
C
C  DETERMINE ENERGY USEAGE
      X=ALOG(AE/DMATX(16,N))
      EER=EXP(5.50543-1.59789*X+.206121*X**2-.005617*X**3)
      COSTO(2)=EER*CKWH/SMATX(2,1)/10.
      SMATX(2,IS2)=SAVE
      RETURN
 1000      IAERF=1
      RETURN
      END
```

```
C
C***************************************************************
C                                                              *
C            UNIT PROCESS NUMBER 10                            *
C                                                              *
C                SLUDGE DRYING BEDS                            *
C                                                              *
C***************************************************************
C
      SUBROUTINE SBEDS
C
      INTEGER OS1,OS2
        COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
C
C  PERFORM FLOW AND MASS BALANCES TO DETERMINE COMPOSITION OF
C  CAKE AND FILTRATE
      SMATX(10,OS1)=DMATX(7,N)*1.E4
      IF (SMATX(10,OS1) .LE. SMATX(10,IS1)) GO TO 1000
      SMATX(10,OS2)=DMATX(2,N)
      SMATX(2,OS1)=SMATX(2,IS1)*(SMATX(10,IS1)-SMATX(10,OS2))/
     2                (SMATX(10,OS1)-SMATX(10,OS2))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
      TEMP=SMATX(10,OS2)/SMATX(10,IS1)
      DO 10 I=3,9
   10 SMATX(I,OS2)=TEMP*SMATX(I,IS1)
      SMATX(20,OS2)=TEMP*SMATX(20,IS1)
      DO 20 I=11,19
   20 SMATX(I,OS2)=SMATX(I,IS1)
      TEMP=SMATX(10,OS1)/SMATX(10,IS1)
      DO 30 I=3,9
30        SMATX(I,OS1)=TEMP*(SMATX(I,IS1)-SMATX(I,OS2))
      SMATX(20,OS1)=TEMP*(SMATX(20,IS1)-SMATX(20,OS2))
      DO 40 I=11,19
40        SMATX(I,OS1)=SMATX(I,IS1)
C
C  DETERMINE BED AREA AND COSTS
      SF=SMATX(10,IS1)/10000.
      SC=DMATX(7,N)
      FSB=(29.84*SF-33.3)/SC
      IF (FSB .LE. 0.) GO TO 1000
      TEMP=SMATX(2,IS1)*SMATX(10,IS1)*249.9
      ASB=TEMP/FSB*DMATX(16,N)
      PSDD=SMATX(10,IS1)*SMATX(2,IS1)*8.33
      X=ALOG(ASB/1000.)
      CCOST(1)=EXP(1.971125+.083841*X+.146751*X**2-.007718*X**3)*
     . 1000.*CCI*RATIO
      X=ALOG(PSDD*365./2000.)
      OHRS=EXP(6.345052-.476780*X+.101319*X**2)
      XMHRS=EXP(4.290089-.098293*X+.075453*X**2)
      TMSU=EXP(.693148+1.000000*X)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      OMATX(1,N)=ASB
      OMATX(2,N)=DMATX(7,N)
C
C  FIND COST OF SLUDGE HOLDING TANKS
      IF (DMATX(6,N) .EQ. 0.) GO TO 50
      VSHT=SMATX(2,IS1)*DMATX(6,N)*1000./7.48*DMATX(15,N)
      X=ALOG(VSHT)
      CCOST(2)=EXP(2.6252751+.484180*X+.000613*X**2+.002252*X**3)
     2           *1000.*CCI*RATIO
      X=ALOG(VSHT/DMATX(15,N))
      OHRS=EXP(5.727345+.000762*X+.098701*X**2-.006786*X**3)
      XMHRS=EXP(4.506628+.214662*X+.071402*X**2-.004681*X**3)
      TMSU=EXP(5.479939+.299282*X+.106008*X**2-.008658*X**3)
      COSTO(2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C  COMPUTE ENERGY USEAGE
50        GPM=SMATX(2,1)*1.E6/1440.
      EER=(.4355*GPM*SF**1.116)*293.*CF/365.
C
C  COMPUTE LAND COSTS
      ALAND=ASB*2.2E-5
      CCOST(3)=DMATX(1,N)*ALAND*RATIO
      RETURN
1000        IAERF=1
      RETURN
      END
```

```
C
C***********************************************************************
C                                                                      *
C            UNIT PROCESS NUMBER 11                                    *
C                                                                      *
C           TRICKLING FILTER - FINAL SETTLER                           *
C                                                                      *
C***********************************************************************
C
      SUBROUTINE TRFS
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2         INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3         ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     4         CF,EEP,EEP,ALAND
C
      IAERF=0
C
      BOD5=DMATX(1,N)
      DEGC=DMATX(2,N)
      HQ=DMATX(3,N)
      SAREA=DMATX(4,N)
      TSS7=DMATX(6,N)*1.E4
      RR=DMATX(7,N)
      GSS=DMATX(8,N)
      YIELD=DMATX(9,N)
      SRATIO=DMATX(10,N)
      TSS5=4.5+.51*BOD5
      IF (TSS5 .GT. DMATX(5,N)) GO TO 200
C
C            COMPUTE REMOVAL EFFICIENCY OF FILTER TO MEET BOD LIMIT
      BOD2=SMATX(8,IS1)+SMATX(17,IS1)
      BOD4=BOD5/(1.-SRATIO)
      IF (TSS7 .EQ. 0.) BOD4=BOD5
      F=BOD4/BOD2
20      IF (F .GT. 1. .OR. F .LT. 0.) GO TO 200
C
C            COMPUTE FILTER AREA AND DEPTH
      BETA=.0245*1.035**(DEGC-20.)
      XN=.91-6.45/SAREA
      A=ALOG((1.+F*RR)/(F+F*RR))/BETA/SAREA
      RHQ=((RR+1.)*HQ)**XN
      DEPTH=RHQ*A
      IF (DEPTH .LE. 30.) GO TO 10
      DEPTH=30.
      RHQ=30./A
      HQ=(1./(RR+1.))*RHQ**(1./XN)
10      FAREA=SMATX(2,IS1)/HQ*43560.
C
C            COMPUTE SLUDGE PRODUCTION
      XVSS=DMATX(9,N)*(BOD2-BOD5)
      TSSIN=SMATX(7,IS1)+XVSS
C
C            COMPUTE FLOW RATES IN EFFLUENT AND SLUDGE STREAMS
      SMATX(10,OS1)=4.5+.51*BOD5
      IF (TSS7 .EQ. 0.) SMATX(10,OS1)=TSSIN
      SMATX(10,OS2)=TSS7
      SMATX(2,OS1)=SMATX(2,IS1)*(SMATX(10,OS2)-TSSIN)/
     2              (SMATX(10,OS2)-SMATX(10,OS1))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
C
C           COMPUTE CONC. OF SOLID SPECIES IN EFFLUENT
      R=SMATX(10,OS1)/TSSIN
      SMATX(3,OS1)=R*XVSS/2.46
      SMATX(4,OS1)=SMATX(3,OS1)*(1.-.6*.8)
      SMATX(5,OS1)=R*(.12*.6+.06*.4)*XVSS
      SMATX(6,OS1)=R*.025*.6*XVSS
      SMATX(7,OS1)=SMATX(7,IS1)*R
      SMATX(8,OS1)=(SMATX(10,OS1)-4.5)*.97
      IF (TSS7 .EQ. 0.) SMATX(8,OS1)=BOD4*(SRATIO+.51*.97*
     2                                (1.-SRATIO))
      SMATX(9,OS1)=SMATX(10,OS1)-SMATX(7,OS1)
C
C           COMPUTE CONC. OF SOLID SPECIES IN SLUDGE
      R1=SMATX(10,OS2)/SMATX(10,OS1)
      DO 50 I=3,9
50      SMATX(I,OS2)=SMATX(I,OS1)*R1
      IF (TSS7 .NE. 0.) SMATX(8,OS2)=.6*.8*.97*SMATX(9,OS2)
C
C           COMPUTE CONC. OF DISSOLVED SPECIES IN EFLLUENT
      SMATX(11,OS1)=SMATX(12,IS1)+(BOD5-SMATX(8,OS1))/BOD2*
     2              (SMATX(11,IS1)-SMATX(12,IS1))
      SMATX(12,OS1)=SMATX(12,IS1)
      SMATX(13,OS1)=SMATX(13,IS1)+SMATX(5,IS1)-SMATX(5,OS1)*
     2              SMATX(2,OS1)/SMATX(2,IS1)-SMATX(5,OS2)*
     3              SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(14,OS1)=SMATX(14,IS1)+SMATX(6,IS1)-SMATX(6,OS1)*
     2              SMATX(2,OS1)/SMATX(2,IS1)-SMATX(6,OS2)*
     3              SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(15,OS1)=SMATX(15,IS1)
      SMATX(17,OS1)=BOD5-SMATX(8,OS1)
      BODLD=BOD2*SMATX(2,IS1)*8.33/FAREA/DEPTH/1000.
      RN=1.-EXP(-.05*BODLD)
      SMATX(18,OS1)=RN*SMATX(18,IS1)
      SMATX(19,OS1)=(1.-RN)*SMATX(18,IS1)+SMATX(19,IS1)
      SMATX(16,OS1)=SMATX(16,IS1)-7.14*(SMATX(18,IS1)-SMATX(18,OS1))
      SMATX(20,OS1)=.6*XVSS*R
      IF (TSS7 .EQ. 0.) GO TO 95
      DO 70 I=11,19
70      SMATX(I,OS2)=SMATX(I,OS1)
      SMATX(20,OS2)=SMATX(20,OS1)*R1
C
C           COMPUTE FILTER COSTS
95      VOL=FAREA*DEPTH*DMATX(16,N)
      X=ALOG(VOL/1000.)
      CCOST(1)=EXP(2.924951+.036285*X+.114673*X**2-
     2              .004587*X**3)*1000.*CCI*RATIO
      X=ALOG(SMATX(2,IS1)/HQ*43560./1000.)
      OHRS=EXP(4.536510-.095731*X+.173718*X**2-.010114*X**3)
      XMHRS=EXP(4.312739-.052122*X+.157473*X**2-.010245*X**3)
      TMSU=EXP(5.105946+.465100*X)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C           COMPUTE SETTLER COSTS
      AFS=0.
      IF (TSS7 .EQ. 0.) GO TO 110
      AFS=SMATX(2,IS1)*1.E6/GSS*DMATX(15,N)
      X=ALOG(AFS/1000.)
      CCOST(2)=EXP(3.716354+.389861*X+.08456*X**2-.004718*X**3)
     2              *1000.*CCI*RATIO
      X=ALOG(AFS/1000./DMATX(15,N))
      OHRS=EXP(5.846565+.254813*X+.113703*X**2-.010942*X**3)
      XMHRS=EXP(5.273419+.228329*X+.122646*X**2-.011672*X**3)
      TMSU=EXP(5.669881+.750799*X)
      COSTO(2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C           COMPUTE PUMPING REQUIREMENTS
110     QP=SMATX(2,IS1)*RR
      X=ALOG(QP*DMATX(14,N))
      CCOST(3)=EXP(3.481553+.377485*X+.093349*X**2-.006222*X**3)
     2              *1000.*CCI*RATIO
      X=ALOG(QP)
      OHRS=EXP(6.097269+.253066*X-.193659*X**2+.078201*X**3
     2            -.00668*X**4)
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2)
      IF (QP-1.44) 120, 130, 130
120     PEFF=.7
      GO TO 160
130     IF (QP-10.08) 140, 150, 150
140     PEFF=.74
      GO TO 160
150     PEFF=.83
160     YRKW=QP*1.E6*(DEPTH+6.)
      YRKW=YRKW/1440./3960./PEFF/.9*.7457*24.*365.
      ECOST=YRKW*CKWH
      SCOST=EXP(5.851743+.30161*X+.197183*X**2-.017962*X**3)
      TMSU=ECOST+SCOST*WPI
      COSTO(3)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
C
C           FILL IN OUTPUT MATRIX VALUES
      OMATX(1,N)=AFS/1000.
      OMATX(2,N)=VOL/1000.
      OMATX(3,N)=FAREA/43560.
      OMATX(4,N)=DEPTH
C
C           COMPUTE ENERGY AND LAND CONSUMPTION
      EER=YRKW/365.
      IF (TSS7 .EQ. 0.) GO TO 170
      X=ALOG(AFS/1000./DMATX(15,N))
      EER=EER+EXP(2.8248+.30093*X+.022308*X**2+.0035144*X**3)
170     ALAND=FAREA/43560.
      RETURN
200     IAERF=1
      RETURN
      END
```

```
C
C****************************************************************
C                                                               *
C            UNIT PROCESS NUMBER 12                             *
C                                                               *
C          CHLORINATION - DECHLORINATION                        *
C                                                ..             *
C****************************************************************
C
      SUBROUTINE CHLOR
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DCL2=DMATX(1,N)
      TCL2=DMATX(2,N)
      CCL2=DMATX(3,N)
      DSO2=DMATX(4,N)
      CSO2=DMATX(5,N)
C
C  COMPUTE BASIN VOLUME AND PROCESS COSTS
      BVOL=SMATX(2,IS1)*TCL2/1.44/7.48*1000.*DMATX(16,N)
      X=ALOG(BVOL/1000.)
      CCOST(1)=EXP(2.048061+.521909*X-.002674*X**2+.004159*X**3)*
     . 1000.*CCI*RATIO
      COSTO(1)=0.
      CUSE=SMATX(2,IS1)*DCL2*8.33*365./2000.
      SUSE=SMATX(2,IS1)*DSO2*8.33*365./2000.
      FACTR=CUSE/(CUSE+SUSE)
      X=ALOG(CUSE*2000./365.*DMATX(15,N)+SUSE*2000./365.*DMATX(14,N))
      XCOST=EXP(2.264294-.044271*X+.065029*X**2-.002536*X**3)*1000.
     2      *CCI*RATIO
      CCOST(2)=FACTR*XCOST
      X=ALOG(CUSE+SUSE)
      OHRS=EXP(4.538517+.543669*X)
      XMHRS=EXP(3.752071-.224812*X+.158849*X**2-.006064*X**3)
      TMSU=EXP(6.126105+.287016*X)
      OC=FACTR*OHRS
      XC=FACTR*XMHRS
      TMSUC=CUSE*CCL2+FACTR*TMSU
      COSTO(2)=((OC+XC)*DHR*(1.+PCT)+TMSUC)/SMATX(2,1)/3650.
      IF(DSO2) 10,10,20
   10 CCOST(3)=0.
      COSTO(3)=0.
      GO TO 30
   20 CCOST(3)=XCOST-CCOST(2)
      OS=OHRS-OC
      XS=XMHRS-XC
      TMSUS=SUSE*CSO2+(1.-FACTR)*TMSU
      COSTO(3)=((OS+XS)*DHR*(1.+PCT)+TMSUS)/SMATX(2,1)/3650.
C
C  COMPUTE COMPOSITION OF EFFLUENT STREAM
   30 DO 40 I=2,20
   40 SMATX(I,OS1)=SMATX(I,IS1)
      OMATX(1,N)=BVOL
      OMATX(2,N)=CUSE
      OMATX(3,N)=SUSE
C
C  COMPUTE ENERGY USEAGE
      PCL2D=DMATX(1,N)*SMATX(2,IS1)*8.33
      X=ALOG(PCL2D)
      EER=0.
      IF(DMATX(4,N).GT.0.)GO TO 50
      EER=EER+EXP(-.071827+.44044*X+.076407*X**2-.003003*X**3)
      GO TO 60
50      EER=EER+EXP(-.259363+.69229*X+.025652*X**2)
60      EEP=0.
      COSTO(4)=EER*CKWH/SMATX(2,1)/10.
      RETURN
      END
```

```
C
C**************************************************************
C                                                             *
C            UNIT PROCESS NUMBER 13                           *
C                                                             *
C      DISSOLVED AIR FLOTATION THICKENING                     *
C                                                             *
C**************************************************************
C
      SUBROUTINE TFLOT
C
      INTEGER OS1,OS2
      DIMENSION Y(12),SMAT(20)
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DATA Y/25.,50.,100.,150.,200.,250.,300.,400.,500.,600.,800.,1000./
      DO 5 I=1,20
    5 SMAT(I)=0.
      IF(IS2) 20,20,10
   10 DO 15 I=1,20
   15 SMAT(I)=SMATX(I,IS2)
   20 SMATX(10,OS1)=DMATX(2,N)
      IF (SMATX(10,OS1) .LE. SMATX(10,IS1)) GO TO 1000
      SMATX(2,OS1)=DMATX(1,N)*(SMATX(2,IS1)*SMATX(10,IS1)+
     . SMAT(2)*SMAT(10))/SMATX(10,OS1)
C
C  COMPUTE THICKENER AREA ON BASIS OF SOLIDS LOADING AND
C  OVERFLOW RATE
      ATH1=(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*
     . 8.33/DMATX(4,N)*168./DMATX(5,N)
      IF(IS2) 30,25,30
   25 ARCY=0.
      GO TO 35
   30 ARCY=.00288*ATH1
      SMATX(2,IS2)=ARCY
   35 SMAT(2)=ARCY
      SMATX(2,OS2)=SMATX(2,IS1)+SMAT(2)-SMATX(2,OS1)
      ATH2=SMATX(2,OS2)*1000000./DMATX(3,N)*168./DMATX(5,N)
      IF(ATH1-ATH2) 40,50,50
   40 ATHM=ATH2*DMATX(16,N)
      GO TO 60
   50 ATHM=ATH1*DMATX(16,N)
C
C  COMPUTE COMPOSITION OF EFFLUENT AND RETURN STREAMS
   60 TEMP=SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10)
      SMATX(10,OS2)=(TEMP-SMATX(2,OS1)*SMATX(10,OS1))/SMATX(2,OS2)
      TEMP=TEMP/(SMATX(2,IS1)+SMAT(2))
      TEMP1=SMATX(10,OS1)/TEMP
      TEMP2=SMATX(10,OS2)/TEMP
      DO 70 I=3,9
      TEMP3=(SMATX(2,IS1)*SMATX(I,IS1)+SMAT(2)*SMAT(I))/
     . (SMATX(2,IS1)+SMAT(2))
      SMATX(I,OS1)=TEMP1*TEMP3
   70 SMATX(I,OS2)=TEMP2*TEMP3
      TEMP3=(SMATX(2,IS1)*SMATX(20,IS1)+SMAT(2)*SMAT(20))/
     2        (SMATX(2,IS1)+SMAT(2))
      SMATX(20,OS1)=TEMP1*TEMP3
      SMATX(20,OS2)=TEMP2*TEMP3
      DO 80 I=11,19
      SMATX(I,OS1)=(SMATX(I,IS1)*SMATX(2,IS1)+SMAT(I)*SMAT(2))
     . /(SMATX(2,IS1)+SMAT(2))
   80 SMATX(I,OS2)=SMATX(I,OS1)
C
C  SELECT STANDARD SIZE THICKENER
      ATHM1=ATHM
      XN=0.
      XX=0.
      K=0
      DO 100 I=1,12
      IF(ATHM-Y(I)) 90,90,95
   90 ATHM=Y(I)
      GO TO 110
   95 IF(I-12) 100,96,100
   96 ATHM=Y(12)
  100 CONTINUE
  110 IF(ATHM-25.) 120,120,130
  120 ATHM=25.
      XN=1.
      GO TO 180
  130 IF(ATHM1-1000.) 170,170,140
  140 XN=ATHM1/1000.
      K=XN
      XX=K
      IF((XN-XX)*1000.-500.) 150,150,160
  150 XN=XX+.5
      GO TO 180
  160 XN=XX+1.
      GO TO 180
  170 ATHM=ATHM/2.
      XN=2.
  180 X=ALOG(ATHM)
C
C  COMPUTE THICKENER COSTS
      CCOST(1)=EXP(1.717538+.453735*X)*1000.*XN*CCI*RATIO
      X=ALOG(ATHM/DMATX(16,N)*XN)
      OHRS=EXP(4.992517-.325053*X+.084026*X**2)
      XMHRS=EXP(4.832373-.336504*X+.083020*X**2)
      HPD=EXP(-1.254959+.852347*X)
      ELEC=HPD*.746*365.*CKWH*DMATX(5,N)/7.
      PWAS=(SMATX(2,IS1)*SMATX(10,IS1)+SMAT(2)*SMAT(10))*8.33
      POLC=PWAS*365./2000.*DMATX(6,N)*DMATX(7,N)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+ELEC+POLC)/
     . SMATX(2,1)/3650.
      OMATX(1,N)=ATHM
      OMATX(2,N)=XN
      OMATX(3,N)=ATHM1
C
C  COMPUTE ENERGY USEAGE
      EER=HPD*.746*DMATX(5,N)/7.
      COSTO(2)=EER*CKWH/SMATX(2,1)/10.
      RETURN
 1000     IAERF=1
      RETURN
      END
```

```
C
C*****************************************************************
C                                                                *
C           UNIT PROCESS NUMBER 14                               *
C                                                                *
C           MULTIPLE HEARTH INCINERATION                         *
C                                                                *
C*****************************************************************
C
      SUBROUTINE MHINC
C
      INTEGER OS1,OS2
      DIMENSION SFHA(59)
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DATA SFHA/85.,98.,112.,125.,126.,140.,145.,166.,187.,193.,208.,
     . 225.,256.,276.,288.,319.,323.,351.,364.,383.,411.,452.,510.,560.,
     . 575.,672.,760.,845.,857.,944.,968.,1041.,1068.,1117.,1128.,1249.,
     . 1260.,1268.,1400.,1410.,1483.,1540.,1580.,1591.,1660.,1675.,
     . 1752.,1849.,1875.,1933.,2060.,2084.,2090.,2275.,2350.,2464.,
     . 2600.,2860.,3120./
C
C  DETERMINE HEARTH AREA
      PSDD=SMATX(10,IS1)*SMATX(2,IS1)*8.33
      FHAT=58.31*SMATX(2,IS1)*SMATX(10,IS1)/DMATX(3,N)/DMATX(1,N)*
     . DMATX(16,N)
      XX=FHAT/DMATX(2,N)
      DO 20 I=1,59
      IF(XX-SFHA(I)) 10,10,20
   10 FHA=SFHA(I)
      GO TO 30
   20 CONTINUE
      FHA=3120.
   30 IF(FHA-200.) 40,40,50
   40 CYT=18.
      GO TO 100
   50 IF(FHA-1700.) 60,60,70
   60 CYT=13.+.024*FHA
      GO TO 100
   70 IF(FHA-2300.) 80,80,90
   80 CYT=.09*(FHA-1100.)
      GO TO 100
   90 CYT=108.
C
C  PERFORM HEAT BALANCE TO DETERMINE FUEL REQUIREMENTS
  100 PASH=(SMATX(10,IS1)-SMATX(9,IS1))/SMATX(9,IS1)
      HASH=68.*PASH
      PWAT=(1000000.-SMATX(10,IS1))/SMATX(9,IS1)
      HWSL=1404.3*PWAT
      SAERA=64.03*FHA**.51
      VSPH=SMATX(9,IS1)*SMATX(2,IS1)*58.31/DMATX(3,N)
      HC=1.735*(1.+.374*DMATX(5,N))
      QTRAN=(1.279+HC)*100.*SAERA*DMATX(2,N)/VSPH
      QCOOL=267.*FHA*DMATX(2,N)/VSPH
      QNET=2725.+HASH+HWSL+QCOOL+QTRAN-DMATX(6,N)+246.
      IF(QNET) 105,105,106
  105 QNET=0.
  106 TEMP=SMATX(9,IS1)*SMATX(2,IS1)*8.33*365.
      QNET=QNET*TEMP
      YSBH=8.*CYT/9.+8736.-52.*DMATX(3,N)*7./9.
      YHUH=10.*CYT/9.+52.*CYT*DMATX(4,N)/9.
      QHUP=YHUH*1913.*FHA*DMATX(2,N)
      QSB=YSBH*315.*FHA*DMATX(2,N)
      QTOT=QHUP+QSB+QNET
      IF(DMATX(7,N)-1.) 130,130,140
  130 WFYR=QTOT/15019.
      FCOST=WFYR/7.481*DMATX(8,N)
      GO TO 180
  140 IF(DMATX(7,N)-2.) 150,150,160
  150 WFYR=QTOT/15581.
      FCOST=WFYR/45.8*DMATX(9,N)
      GO TO 180
  160 IF(DMATX(7,N)-3.) 170,170,180
  170 CFDG=QTOT/8967./.0695
      FCOST=0.
C
C  COMPUTE INCINERATOR COSTS
  180 TYR=SMATX(10,IS1)*SMATX(2,IS1)*1.52
      WTON=554.24/FHA**.3572
      ECOST=WTON*TYR*CKWH
      DPTON=FCOST/(PSDD*365./2000.)
      X=ALOG(PSDD/24.*DMATX(16,N))
      CCOST(1)=EXP(2.377364+.598986*X)*1000.*CCI*RATIC
      X=ALOG(PSDD*365./2000.*(SMATX(9,IS1)/SMATX(10,IS1)))
      OHRS=EXP(3.402537+1.215130*X-.157203*X**2+.009771*X**3)
      XMHRS=EXP(3.906553+.702471*X-.088337*X**2+.006827*X**3)
      TMSU=EXP(7.864729-.338816*X+.054026*X**2)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI+ECOST+FCOST)/
     . SMATX(2,1)/3650.
      OMATX(1,N)=FHA
      OMATX(2,N)=WFYR
      OMATX(3,N)=PSDD
      OMATX(4,N)=ECOST
      OMATX(5,N)=FCOST
      OMATX(6,N)=CFDG
C
C  COMPUTE ENERGY USEAGE AND ENERGY CONTENT OF EXHAUST GAS
      EER=ECOST/CKWH/365.+QTOT/365.*.000293*CF
      FS=SMATX(10,IS1)/1.E6
      FV=SMATX(9,IS1)/SMATX(10,IS1)
      WS=(1.-FS)/(FS*FV)
      EX=-((QNET-2725.)-2113.)/1223.
      IF(EX.LT..5)EX=.5
      IF(EX.GT.1.5)EX=1.5
      QPDVS=(800.-60.)*(.505*WS+2.55+2.09*EX)
      IF=DMATX(7,N)
      GO TO (190,200,210),IF
190      F1=4.136
      F2=WFYR
      GO TO 220
200      F1=5.63
      F2=WFYR
      GO TO 220
210      F1=3.151
      F2=CFDG*.0695
220      QPD=QPDVS*SMATX(9,IS1)*SMATX(2,IS1)*8.33
      QPD=QPD+(800.-60.)/365.*F1*F2
      EEP=QPD*.000293*DMATX(10,N)
C
C  COMPUTE AIR POLLUTION CONTROL COSTS
      CCOST(2)=CCOST(1)*DMATX(11,N)
      COSTO(2)=COSTO(1)*DMATX(12,N)
C
C  COMPUTE ASH DISPOSAL COSTS
      ASH=SMATX(2,IS1)*SMATX(7,IS1)*8.33/2000.
      COSTO(3)=ASH*DMATX(13,N)/SMATX(2,1)/10.
      DO 230 I=1,20
230      SMATX(I,OS1)=0.
      OMATX(7,N)=ASH
      RETURN
      END
```

```
C
C*************************************************************
C                                                            *
C           UNIT PROCESS NUMBER 15                           *
C                                                            *
C             RAW WASTEWATER PUMPING                         *
C                                                            *
C*************************************************************
C
      SUBROUTINE RWP
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
      HEAD=DMATX(1,N)
      QP=1.78*SMATX(2,IS1)**.92
      X=ALOG(QP*DMATX(16,N))
      CCOST(1)=EXP(4.004828+.519499*X+.082262*X**2-.006492*X**3)*
     . 1000.*CCI*RATIO
      X=ALOG(SMATX(2,IS1))
      OHRS=EXP(6.097269+.253066*X-.193659*X**2+.078201*X**3-
     . .006680*X**4)
      XMHRS=EXP(5.911541-.013158*X+.076643*X**2)
      IF(SMATX(2,IS1)-1.44) 20,30,30
   20 PEFF=.70
      GO TO 60
   30 IF(SMATX(2,IS1)-10.08) 40,50,50
   40 PEFF=.74
      GO TO 60
   50 PEFF=.83
   60 YRKW=SMATX(2,IS1)*1000000.*HEAD/1440./3960./PEFF/.9*.7457*24.*365.
      ECOST=YRKW*CKWH
      SCOST=EXP(5.851743+.301610*X+.197183*X**2-.017962*X**3)
      TMSU=ECOST+SCOST*WPI
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
      OMATX(1,N)=QP
      EER=YRKW/365.
      RETURN
      END
```

```
C
C***********************************************************************
C                                                                      *
C            UNIT PROCESS NUMBER 16                                    *
C                                                                      *
C               SLUDGE HOLDING TANKS                                   *
C                                                                      *
C***********************************************************************
C
      SUBROUTINE SHT
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DO 10 I=2,20
   10 SMATX(I,OS1)=SMATX(I,IS1)
      VSHT=SMATX(2,IS1)*DMATX(1,N)*1000./7.48*DMATX(16,N)
      X=ALOG(VSHT)
      CCOST(1)=EXP(2.625751+.484180*X+.000613*X**2+.002252*X**3)*
     . 1000.*CCI*RATIO
      V1=SMATX(2,IS1)*DMATX(1,N)*1000./7.48
      X=ALOG(V1)
      OHRS=EXP(5.727345+.000762*X+.098701*X**2-.006786*X**3)
      XMHRS=EXP(4.506628+.214662*X+.071402*X**2-.004681*X**3)
      TMSU=EXP(5.479939+.299282*X+.106008*X**2-.008658*X**3)
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      OMATX(1,N)=VSHT
      EER=0.
      RETURN
      END
```

```
C
C***********************************************************************
C                                                                      *
C            UNIT PROCESS NUMBER 17                                    *
C                                                                      *
C                CENTRIFUGATION                                        *
C                                                                      *
C***********************************************************************
C
      SUBROUTINE CENT
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      HPWK=DMATX(1,N)
      GPMM=SMATX(2,IS1)*1.E6/1440.
      CGPM=GPMM*168./HPWK
      CAKE=DMATX(5,N)*1.E4
C
      POLY=DMATX(6,N)
      CPOLY=DMATX(2,N)
      SAVE1=SMATX(7,IS1)
      SAVE2=SMATX(10,IS1)
C
C  COMPUTE COMPOSITON OF CAKE AND FILTRATE
      SMATX(7,IS1)=SMATX(7,IS1)+POLY*SMATX(10,IS1)/2000.
      SMATX(10,IS1)=SMATX(10,IS1)+POLY*SMATX(10,IS1)/2000.
      DSOL=SMATX(10,IS1)*SMATX(2,IS1)*8.33*365./2000.
      SMATX(10,OS2)=((1.-DMATX(4,N))/(1.-DMATX(4,N)*SMATX(10,IS1)/
     . CAKE))*SMATX(10,IS1)
      TEMP1=CAKE/SMATX(10,IS1)
      TEMP2=SMATX(10,OS2)/SMATX(10,IS1)
      SMATX(10,OS1)=CAKE
      IF (SMATX(10,OS1) .LE. SMATX(10,IS1)) GO TO 1000
      SMATX(2,OS1)=(SMATX(10,IS1)-SMATX(10,OS2))*SMATX(2,IS1)/
     . (SMATX(10,OS1)-SMATX(10,OS2))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
      DO 11 I=3,9
      SMATX(I,OS1)=TEMP1*SMATX(I,IS1)
   11 SMATX(I,OS2)=TEMP2*SMATX(I,IS1)
      SMATX(20,OS1)=TEMP1*SMATX(20,IS1)
      SMATX(20,OS2)=TEMP2*SMATX(20,IS1)
      DO 21 I=11,19
      SMATX(I,OS1)=SMATX(I,IS1)
   21 SMATX(I,OS2)=SMATX(I,IS1)
C
C  COMPUTE CENTRIFUGATION COSTS
      X=ALOG(CGPM*DMATX(16,N))
      CCOST(1)=EXP(4.7185-.0334457*X+.06116958*X**2)*
     2           1000.*CCI*RATIO
      PWF1=1./(1.+RI)**10
      PWF2=1./(1.+RI)**YRS
      ACOST(1)=CCOST(1)*AF*(1.-PWF2)/(1.-PWF1)/SMATX(2,1)/3650.
      X=ALOG(DSOL)
   40 OHRS=EXP(7.264153-.466246*X+.069552*X**2)
   50 XMHRS=EXP(5.997115-.493809*X+.070892*X**2)
      SUPP=EXP(-2.822519+.700948*X)*1000.
      CHEM=DSOL*POLY*CPOLY
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+SUPP*WPI+CHEM)/
     . SMATX(2,1)/3650.
      OMATX(1,N)=CGPM
      OMATX(2,N)=DSOL
      OMATX(3,N)=AF*(1.-PWF2)/(1.-PWF1)
      OMATX(4,N)=DMATX(4,N)
      OMATX(5,N)=DMATX(5,N)
      OMATX(6,N)=DMATX(6,N)
      SMATX(7,IS1)=SAVE1
      SMATX(10,IS1)=SAVE2
C
C  COMPUTE ENERGY USEAGE
      EER=GPMM*.7457*24.
      COSTO(2)=EER*CKWH/SMATX(2,1)/10.
      RETURN
1000      IAERF=1
      RETURN
      END
```

```
C
C******************************************************************
C                                                                 *
C            UNIT PROCESS NUMBER 18                               *
C                                                                 *
C                  AEROBIC DIGESTION                              *
C                                                                 *
C******************************************************************
C
      SUBROUTINE AEROB
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2         INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3         ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     4         CF,EER,EEP,ALAND
C
      DEGC=DMATX(1,N)
      DTA=DMATX(2,N)
      CB1 =DMATX(3,N)
      CY  =DMATX(4,N)
      CKN =DMATX(5,N)
      AEFF=DMATX(6,N)
C
C   COMPUTE INFLUENT BIOMASS, REFRACTORIES,  AND BOD
      XASSIN=SMATX(20,IS1)
      XRSSIN=SMATX(9,IS1)-XASSIN
      SIN=SMATX(8,IS1)+SMATX(17,IS1)-.97*.8*XASSIN
C
C
C   FIND EFFLUENT SOLIDS CONC.
        CB=CB1*(1.05)**(DEGC-20.)
      XASS=(XASSIN+CY*SIN)/(1.+.8*CB*DTA)
      IF (XASS .GT. XASSIN) GO TO 40
      XRSS=XRSSIN+.2*CB*XASS*DTA
      GO TO 50
40      XASS=XASSIN
      XRSS=XRSSIN
50      XVSS=XASS+XRSS
      TSS=SMATX(7,IS1)+XVSS
C
C   FIND FLOW RATES IN OUTPUT STREAMS
60      SMATX(10,OS1)=TSS
      SMATX(10,OS2)=0.
      SMATX(2,OS1)=SMATX(2,IS1)
      SMATX(2,OS2)=0.
C
C   DETERMINE EFFLUENT SOLIDS CONC.
70      SMATX(3,OS1)=XVSS/2.46
      SMATX(4,OS1)=SMATX(3,OS1)*(XRSS+.2*XASS)/XVSS
      SMATX(5,OS1)=(.06*XRSS+.12*XASS)
      SMATX(6,OS1)=(.025*XASS)
      SMATX(7,OS1)=SMATX(7,IS1)
      SMATX(8,OS1)=.97*.8*XASS
      SMATX(9,OS1)=XVSS
      SMATX(20,OS1)=XASS
      DO 80 I=3,9
80       SMATX(I,OS2)=0.
      SMATX(20,OS2)=0.
C
C   DETERMINE EFFLUENT CONC. OF SOLUBLE C, N, P, AND FIXED MATTER
      SMATX(12,OS1)=SMATX(12,IS1)
      SMATX(11,OS1)=SMATX(12,OS1)
      SMATX(13,OS1)=SMATX(13,IS1)+SMATX(5,IS1)-SMATX(5,OS1)*SMATX(2,OS1)
     2 /SMATX(2,IS1)-SMATX(5,OS2)*SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(14,OS1)=SMATX(14,IS1)+SMATX(6,IS1)-SMATX(6,OS1)*SMATX(2,OS1)
     2 /SMATX(2,IS1)-SMATX(6,OS2)*SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(15,OS1)=SMATX(15,IS1)
C
C   CHECK FOR NITRIFICATION
      IF(DTA.LT.5.) GO TO 90
      IF(CKN.EQ.0.) GO TO 90
      CKN=CKN*1.05**(DEGC-20.)
      SMATX(18,OS1)=1./(DTA*.05*CKN-1.)
      SMATX(19,OS1)=SMATX(13,OS1)-SMATX(18,OS1)
      GO TO 100
90       SMATX(19,OS1)=SMATX(19,IS1)
      SMATX(18,OS1)=SMATX(13,OS1)-SMATX(19,OS1)
C
C   ADJUST ALKALINITY AND SOLUBLE BOD
100       SMATX(16,OS1)=SMATX(16,IS1)-7.14*(SMATX(19,OS1)-SMATX(19,IS1))
      IF(SMATX(16,OS1).LT.20.)SMATX(16,OS1)=20.
      SMATX(17,OS1)=1.
      IF(SMATX(2,OS2).EQ.0.) GO TO 120
      DO 110 I=11,19
110       SMATX(I,OS2)=SMATX(I,OS1)
      GO TO 140
120       DO 130 I=11,19
130       SMATX(I,OS2)=0.
C
C   SIZE DIGESTOR
140       VAER=DTA*SMATX(2,IS1)*DMATX(16,N)*1000./7.48
             IF(VAER.LE.0.)WRITE(IO,1000)N,IS1,SMATX(2,IS1)
1000              FORMAT(/' AEROB:',2I5,E12.4)
      X=ALOG(VAER)
      CCOST(1)=EXP(2.414380+.175682*X+.084742*X**2-.002670*X**3)*1.E3
     2           *CCI*RATIO
      COSTO(1)=0.
C
C   COMPUTE AIR REQUIREMENTS
      ACFM=(1.5-1.42*CY)*SMATX(2,IS1)*SIN*8.33
      ACFM=ACFM+1.42*CB*.8*XASS*VAER*1.E3*7.48*8.33/1.E6
      ACFM=ACFM+4.6*(SMATX(19,OS1)-SMATX(19,IS1))*SMATX(2,IS1)*8.33
      ACFM=ACFM/AEFF/.232/.075/1440.*DMATX(15,N)
      IF(20.*VAER*DMATX(15,N).GT.ACFM)ACFM=20.*VAER*DMATX(15,N)
      X=ALOG(ACFM/1000.)
      CCOST(2)=EXP(4.145454+.633339*X+.031939*X**2-.002419*X**3)*1.E3
     2           *CCI*RATIO
      XX=ACFM/1000./DMATX(15,N)
      X=ALOG(XX)
      IF(XX.GE.1.)GO TO 150
      OHRS=850.
      XMHRS=350.
      GO TO 160
150      OHRS=EXP(6,900586+,323725*X+,059093*X**2-,004926*X**3)
      XMHRS=EXP(6,169937+,294853*X+,17599*X**2-,040947*X**3+,0033*X**4)
160      HP=ACFM/DMATX(15,N)*6,1*144,/(33000,*,8)
      XKW=,8*HP
      XKWPY=XKW*24,*365,
      ECOST=XKWPY*CKWH
      SCOST=1000,*EXP(,62138+,482047*X)
      TMSU=ECOST+SCOST*WPI
      COSTO(2)=((OHRS+XMHRS)*DHR*(1,+PCT)+TMSU)/SMATX(2,1)/3650,
C
C   ASSIGN VALUES TO OUTPUT MATRIX
      OMATX(1,N)=VAER
      OMATX(2,N)=ACFM
C
C   COMPUTE ENERGY REQUIREMENTS
      EER=XKWPY/365,
      RETURN
      END
```

```
C
C************************************************************
C                                                          *
C           UNIT PROCESS NUMBER 22                         *
C                                                          *
C           TRUCK TRANSPORT - LAND DISPOSAL                *
C                                                          *
C************************************************************
C
C
      SUBROUTINE LANDD
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2        INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3        ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     4        CF,EER,EEP,ALAND
      DIMENSION CAPAC(6),TRUCK(6),OPER(6),TMPG(6)
      DATA CAPAC/1200.,2500.,5500.,10.,15.,30./
      DATA TRUCK/25000.,42000.,55000.,25000.,42000.,50000./
      DATA OPER/.2,.25,.3,.2,.25,.3/
      DATA TMPG/4.5,4.5,3.5,4.5,4.5,3.5/
C
      WHPY=DMATX(1,N)
      DIST=DMATX(2,N)
      YRSL=DMATX(3,N)
      FCOST=DMATX(4,N)
      SP=DMATX(7,N)
      TNMAX=DMATX(8,N)
      RA=DMATX(9,N)
      ECFT=DMATX(15,N)
      PWF1=1./(1.+RI)**YRS
      PWF2=1./(1.+RI)**YRSL
C
C          COMPUTE HAULING COSTS
C
      SLV=0.
      JSTYPE=0
      WS=(SMATX(10,IS1)+SMATX(15,IS1))*SMATX(2,IS1)*8.33
      WW=SMATX(2,IS1)*8.33E6-WS
      IF(WS/(WS+WW).GE.0.15) JSTYPE=1
      IF(JSTYPE.EQ.1)GO TO 10
      ASV=SMATX(2,IS1)*365.E6
      J1=0
      GO TO 20
10      ASV=(WS+WW)*365./55./27.
      J1=3
20      CT=1.E20
      ARS=25.
      IF(DIST.GT.20.)ARS=(25.*20./DIST)+(35.*(DIST-20.)/DIST)
      AHPT=(2.*DIST/ARS)+.75
      TPTPY=WHPY/AHPT
      DO 30 KTYPE=1,3
      TPY=ASV/CAPAC(J1+KTYPE)
      NT=TPY/TPTPY*ECFT+.9999999
      ATM=TPY*2.*DIST                                        ...
      FUEL=ATM/TMPG(J1+KTYPE)
      TMHPY=AHPT*TPY*1.1
      CC=NT*TRUCK(J1+KTYPE)*WPI*118.2/150.2*RATIO
      CA=CC*(1.-PWF1)/(1.-PWF2)*(1.-.15*PWF2)*AF
      CO=FUEL*FCOST+ATM*OPER(J1+KTYPE)*WPI*117.5/170.3
      CO=CO+TMHPY*DHR*(1.+PCT)
      IF(CA+CO.GE.CT)GO TO 30
      CT=CA+CO
      CCOST(2)=CC
      ACOST(2)=CA
      COSTO(2)=CO
      EER=FUEL
      OMATX(1,N)=TPY/NT
      OMATX(2,N)=TPY
      OMATX(3,N)=NT
 30     CONTINUE
      EER=EER*140000.*.000293*CF/365.
C
C           ADD ON FACILITY COSTS
      IF(JSTYPE.EQ.1)GO TO 25
      Q=ASV/1.E6
      C1=20015.*Q**.32
      C2=19950.*Q**.40
      C3=  936.*Q**.22
      C4=  900.*Q**.3
      GO TO 28
 25     Q=ASV/1.E3
      IF(Q.LT.15.)GO TO 26
      C1=13849.*Q**.32
      GO TO 27
 26     C1=32387.
 27     C2=17700.*Q**.40
      C3=  936.*Q**.22
      C4=  900.*Q**.3
 28     CCOST(2)=CCOST(2)+C1*CCI*RATIO
      ACOST(2)=(ACOST(2)+C1*CCI*RATIO*AF)/SMATX(2,1)/3650.
      TMSU=C2*CKWH+C3*WPI
      COSTO(2)=(COSTO(2)+(C4*DHR*(1.+PCT)+TMSU))
      COSTO(2)=COSTO(2)/SMATX(2,1)/3650.
      EER=EER+C2/365.
C
C                COMPUTE STORAGE COSTS
C
      TONS=WS*365./2000.
      IF(DMATX(6,N).GT.0.)GO TO 60
      ALAND=SMATX(2,IS1)*(SMATX(5,IS1)+SMATX(13,IS1))*3040./TNMAX
      IF(JSTYPE.EQ.1)GO TO 50
      SLV=SP*365.*SMATX(2,IS1)*1.E6/7.48/1.E3*DMATX(16,N)
      IF(SLV.LE.0.)GO TO 40
      X=ALOG(SLV)
      CCOST(1)=EXP(.375449+.394996*X+.014726*X**2)*1000.*CCI*RATIO
 40     IF(TONS.LE.0.)GO TO 50
      X=ALOG(TONS)
      OHRS=EXP(6.567594-.971759*X+.095689*X**2)*SP
      XMHRS=EXP(-2.087393+2.395831*X-.340388*X**2+
     2            .017499*X**3)*SP
```

```
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT))/SMATX(2,1)/3650.
C
C           COMPUTE LAND AND APPLICATION COSTS
C
50      CAF=(1.+RA)**YRS
      CCOST(4)=ALAND*DMATX(5,N)*RATIO
      ACOST(4)=AF*CCOST(4)*(1.-CAF*PWF1)/SMATX(2,1)/3650.
      IF(JSTYPE.EQ.1)GO TO 55
      EER=EER+180.*SMATX(2,IS1)*293.*CF
      CCOST(4)=ALAND*DMATX(10,N)*RATIO
      COSTO(4)=TONS*DMAIX(11,N)/SMATX(2,1)/3650.
      GO TO 70
55      EER=EER+71.43*ASV/1000.*293.*CF/365.
      CCOST(3)=ALAND*DMATX(12,N)*RATIO
      COSTO(3)=TONS*DMATX(13,N)/SMATX(2,1)/3650.
      GO TO 70
C
C           COMPUTE LANDFILL COSTS
C
60      WTPD=TONS/365.+WW/2000.
      IF (JSTYPE .EQ. 0) GO TO 1000
      ALAND=3.75E-3*WTPD*365.
      CCOST(3)=(ALAND*DMATX(5,N)+1.E4*(WTPD**.74)*1.506/2.4*CCI)
     2          *RATIO
      COSTO(3)=9480.*(WTPD**.625)*1.192/1.7*WPI/SMATX(2,1)/3650.
      EER=EER+18.*ASV/1000.*293.*CF/365.
C
C           FILL IN OUTPUT DATA
C
70      OMATX(4,N)=SLV
      OMATX(5,N)=TONS
      OMATX(6,N)=ALAND
      OMATX(7,N)=ALAND*DMATX(5,N)
      OMATX(8,N)=ALAND*DMATX(5,N)*CAF*PWF1
      IF (DMATX(6,N) .GT. 0.) OMATX(8,N)=0.
      OMATX(9,N)=AF*(1.-PWF1)/(1.-PWF2)*(1.-.15*PWF2)
      DO 80 I=1,20
80      SMATX(I,OS1)=0.
      RETURN
1000      IAERF=1
      RETURN
      END
```

```
C
C*************************************************************
C                                                            *
C           UNIT PROCESS NUMBER 23                           *
C                                                            *
C                 LIME STABILIZATION                         *
C                                                            *
C*************************************************************
C
      SUBROUTINE LIME
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      DLIME=DMATX(1,N)
      CLIME=DMATX(2,N)
      DTON=(SMATX(10,IS1)+SMATX(15,IS1))*SMATX(2,IS1)*8.33/2000.
      PPDL=DLIME*DTON*DMATX(16,N)
      DO 10 I=2,6
   10 SMATX(I,OS1)=SMATX(I,IS1)
      SMATX(7,OS1)=SMATX(7,IS1)+PPDL/8.33/SMATX(2,IS1)
      SMATX(8,OS1)=SMATX(8,IS1)
      SMATX(9,OS1)=SMATX(9,IS1)
      SMATX(10,OS1)=SMATX(10,IS1)+PPDL/8.33/SMATX(2,IS1)
      SMATX(20,OS1)=0.
      DO 20 I=11,19
   20 SMATX(I,OS1)=SMATX(I,IS1)
      X=ALOG(PPDL)
      CCOST(1)=EXP(-1.800487+.670797*X)*1000.*CCI*RATIO
      X=ALOG(PPDL/DMATX(16,N))
      OHRS=0.
      XMHRS=EXP(6.060054+.197073*X)
      CHEM=PPDL*365.*CLIME/2000.
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+CHEM)/
     . SMATX(2,1)/3650.
      OMATX(1,N)=PPDL
      OMATX(2,N)=DTON
      EER=EXP(2.077+.001*1.32*DLIME+.7*ALOG(DTON*2000.))/365.
      COSTO(2)=EER*CKWH/SMATX(2,1)/10.
      RETURN
      END
```

```
C
C**********************************************************************
C                                                                     *
C            UNIT PROCESS NUMBER 24                                   *
C                                                                     *
C      ROTATING BIOLOGICAL CONTACTOR - FINAL SETTLER                  *
C                                                                     *
C**********************************************************************
C
      SUBROUTINE RBC
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     . INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     . ACOST(5), DHR,PCT,WPI,CCI,RI,AF,RATIO ,CKWH,YRS,
     . CF,EER,EEP,ALAND
C
      BOD=DMATX(1,N)
      XNSTG=DMATX(2,N)
      DEGC=DMATX(3,N)
      QPABI=DMATX(4,N)
      QPANI=DMATX(5,N)
      GSS=DMATX(6,N)
      BODN=DMATX(7,N)
      TSS=DMATX(8,N)
      CPDY=DMATX(9,N)
      YIELD=DMATX(10,N)
C
C  COMPUTE REQUIRED NO. OF 100,000 SQ FT SHAFTS
      QPAB=DMATX(4,N)*1.04**(DMATX(3,N)-20.)
      QPAN=DMATX(5,N)*1.04**(DMATX(3,N)-20.)
      RBOD=DMATX(1,N)/(SMATX(17,IS1)+SMATX(8,IS1))
      IF (RBOD .GE. 1.) GO TO 1000
      TEMP1=ALOG(RBOD)/DMATX(2,N)
      TEMP2=1./EXP(TEMP1)-1.
      APSTG=SMATX(2,IS1)*1000000.*TEMP2/QPAB
      NTRN=APSTG*DMATX(16,N)/1.E5
      NTRN=NTRN+1
      NSHFT=NTRN*XNSTG
      XNTRN=NTRN
      XSHFT=NSHFT
      AREA=XSHFT*1.E5
      TEMP3=1./(1.+QPAB*APSTG/SMATX(2,IS1)/1000000.)
      RBOD=DMATX(7,N)/(SMATX(17,IS1)+SMATX(8,IS1))
      FNSTG=ALOG(RBOD)/ALOG(TEMP3)
      RNSTG=XNSTG-FNSTG
      IF (RNSTG.LT.0.) RNSTG=0.
      RNH3=(1./(1.+QPAN*APSTG/SMATX(2,IS1)/1000000.))**RNSTG
C
C  COMPUTE SLUDGE PRODUCTION
      XVSS=YIELD*(SMATX(8,IS1)+SMATX(17,IS1)-BOD)
      TSSIN=SMATX(7,IS1)+XVSS
C
C  COMPUTE FLOW AND SOLIDS CONC. IN EFFLUENT AND SLUDGE
      SMATX(10,OS1)=4.5+.51*BOD
      SMATX(10,OS2)=TSS*1.E4
      SMATX(2,OS1)=SMATX(2,IS1)*(SMATX(10,OS2)-TSSIN)/
     2              (SMATX(10,OS2)-SMATX(10,OS1))
      SMATX(2,OS2)=SMATX(2,IS1)-SMATX(2,OS1)
      URSS=SMATX(10,OS1)/TSSIN
C
C  COMPUTE CONC. OF SUSPENDED SPECIES IN EFFLUENT AND SLUDGE
      SMATX(3,OS1)=URSS*XVSS/2.46
      SMATX(4,OS1)=SMATX(3,OS1)*(1.-.6*.8)
      SMATX(5,OS1)=URSS*(.12*.6+.06*.4)*XVSS
      SMATX(6,OS1)=URSS*.025*.6*XVSS
      SMATX(7,OS1)=SMATX(7,IS1)*URSS
      SMATX(8,OS1)=(SMATX(10,OS1)-4.5)*.97
      SMATX(9,OS1)=SMATX(10,OS1)-SMATX(7,OS1)
      TEMP4=SMATX(10,OS2)/SMATX(10,OS1)
      DO 60 J=3,9
60      SMATX(J,OS2)=SMATX(J,OS1)*TEMP4
      SMATX(20,OS1)=.6*XVSS*URSS
      SMATX(20,OS2)=SMATX(20,OS1)*TEMP4
      SMATX(8,OS2)=.6*.8*.97*SMATX(9,OS2)
C
C  COMPUTE CONC. OF DISSOLVED SPECIES IN EFFLUENT AND SLUDGE
      SMATX(11,OS1)=SMATX(12,IS1)+BOD/(SMATX(8,IS1)+SMATX(17,IS1))
     2              *(SMATX(11,IS1)-SMATX(12,IS1))
      SMATX(12,OS1)=SMATX(12,OS1)
      SMATX(13,OS1)=SMATX(13,IS1)+SMATX(5,IS1)-SMATX(5,OS1)*
     2              SMATX(2,OS1)/SMATX(2,IS1)-SMATX(5,OS2)*
     3              SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(14,OS1)=SMATX(14,IS1)+SMATX(6,IS1)-SMATX(6,OS1)*
     2              SMATX(2,OS1)/SMATX(2,IS1)-SMATX(6,OS2)*
     3              SMATX(2,OS2)/SMATX(2,IS1)
      SMATX(15,OS1)=SMATX(15,IS1)
      SMATX(17,OS1)=BOD-SMATX(8,OS1)
      SMATX(18,OS1)=SMATX(18,IS1)*RNH3
      SMATX(19,OS1)=SMATX(18,IS1)-SMATX(18,OS1)
      SMATX(16,OS1)=SMATX(16,IS1)-7.14*(SMATX(19,OS1)-
     2              SMATX(19,IS1))
      DO 70 J=11,19
70      SMATX(J,OS2)=SMATX(J,OS1)
C
C  SIZE FINAL SETTLER
      AFS=SMATX(2,OS1)*1000000./DMATX(6,N)*DMATX(15,N)
      PREM=(SMATX(18,IS1)-SMATX(18,OS1))*100./SMATX(18,IS1)
      QPAT=SMATX(2,IS1)*1000000./APSTG/XNSTG
C
C  COMPUTE COSTS OF CONTACTOR AND FINAL SETTLER
      IF(NSHFT-20) 80,80,90
80      CCOST(1)=(28500.+45.*DMATX(9,N)/CCI)*NSHFT*1.506/2.1215
     2        *CCI*RATIO
      GO TO 100
90      CCOST(1)=(23000.+45.*DMATX(9,N)/CCI)*NSHFT*1.506/2.1215
     2        *CCI*RATIO
  100 X=ALOG(AREA/1000./DMATX(16,N))
      OHRS=EXP(1.323670+.524215*X+.023076*X**2)
      XMHRS=EXP(-.124185+.840104*X+.007757*X**2)
      COSTL=(OHRS+XMHRS)*DHR*(1.+PCT)
      COSTM=28500.*NSHFT*1.506/2.1215*CCI*.02
      IF (NSHFT .GT. 20) COSTM=23000.+NSHFT*1.506/2.1215*CCI*.02
      COSTE=NSHFT*5.*.746*24.*365.*CKWH
      TMSU=COSTM+COSTE
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
      X=ALOG(AFS/1000.)
      CCOST(2)=EXP(3.716354+.389861*X+.084560*X**2-.004710*X**3)*
     . 1000.
      X=ALOG(AFS/1000./OMATX(15,N))
      OHRS=EXP(5.846565+.254813*X+.113703*X**2-.010842*X**3)
      XMHRS=EXP(5.273419+.228329*X+.122968*X**2-.011672*X**3)
      TMSU=EXP(5.669881+.750799*X)
      COSTO(2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
      OMATX(1,N)=QPAB
      OMATX(2,N)=QPAN
      OMATX(3,N)=APSTG
      OMATX(4,N)=AREA
      OMATX(5,N)=FNSTG
      OMATX(6,N)=RNSTG
      OMATX(7,N)=RBOD
      OMATX(8,N)=PREM
      OMATX(9,N)=QPAT
      OMATX(10,N)=AFS
      OMATX(11,N)=SMATX(2,OS2)*SMATX(10,OS2)*8.33
      OMATX(12,N)=URSS
      OMATX(13,N)=XNTRN
      OMATX(14,N)=XSHFT
      OMATX(15,N)=COSTM
      OMATX(16,N)=COSTE
      OMATX(17,N)=COSTL
C
C  COMPUTE ENERGY CONSUMPTION
      EER=COSTE/365./CKWH
      EER=EER+EXP(2.8248+.30093*X+.022308*X**2+
     2              .0035144*X**3)
      RETURN
1000      IAERF=1
      RETURN
      END
```

```
C
C*****************************************************************
C                                                               *
C          UNIT PROCESS NUMBER 25                               *
C                                                               *
C    PRIMARY SEDIMENTATION - ACTIVATED SLUDGE - WASTE           *
C    ACTIVATED SLUDGE RETURNED TO PRIMARY CLARIFIER             *
C                                                               *
C*****************************************************************
C
      SUBROUTINE PSAS
C
      INTEGER OS1,OS2,OS11,OS12,OS21,OS22,OS1SAV,OS2SAV
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     1       INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     2       ACOST(5),DMR,PCT,WPI,CCI,RI,AF,RATIO,CRRN,YRS,
     3       CF,ELP,EFF,ALAND
      DIMENSION TRECYC(20),CTEMP(5),TEMPO(5),ATEMP(5)
C
C          SAVE STREAM AND PROCESS ID NUMBERS
C
      NITER=1
      IS1SAV=IS1
      OS1SAV=OS1
      OS2SAV=OS2
      NSAVE=N
      N1=DMATX(1,N)
      N2=DMATX(2,N)
      EPS=.001
      NITMAX=20
C
C              IS11 = INFLUENT STRM TO PRI. SETTLER
C                     (INCLUDES WASTE ACT. SLUDGE)
C             OS11 = EFFLUENT STRM FROM PRI. SETTLER
C             OS12 = SLUDGE STRM FROM PRI. SETTLER
C             OS21 = EFFLUENT STRM FROM FINAL SETTLER
C             OS22 = SLUDGE STRM FROM FINAL SETTLER
C
      IS11=OS2+1
      OS11=OS2+2
      OS12=OS2
      OS21=OS1
      OS22=OS2+3
      DO 10 I=2,20
      SMATX(I,OS22)=0.
   10   TRECYC(I)=0.
C
C          MIX STREAM IS1SAV WITH OS22
C
   20   TEMP1=SMATX(2,OS22)+SMATX(2,IS1SAV)
      DO 30 I=3,20
      TEMP2=SMATX(2,OS22)*SMATX(I,OS22)
      TEMP2=TEMP2+SMATX(2,IS1SAV)*SMATX(I,IS1SAV)
   30   SMATX(I,IS11)=TEMP2/TEMP1
      SMATX(2,IS11)=TEMP1
      FPS=SMATX(2,IS1SAV)*SMATX(10,IS1SAV)
      FPS=FPS/(FPS+SMATX(2,OS22)*SMATX(10,OS22))
C
C           EVALUATE PROCESS PERFORMANCES .
C
      N=N1
      IS1=IS11
      OS1=OS11
      OS2=OS12
      DO 40 I=1,5
      CCOST(I)=0.
      COSTO(I)=0.
40      ACOST(I)=0.
      CALL PRSET
      DO 45 I=1,5
      CTEMP(I)=CCOST(I)
      TEMPO(I)=COSTO(I)
45      ATEMP(I)=ACOST(I)
      EERIMP=EER
      N=N2
      IS1=OS11
      OS1=OS21
      OS2=OS22
      DO 50 I=1,5
      CCOST(I)=0.
      ACOST(I)=0.
50      COSTO(I)=0.
      CALL AERFS
      IF(IAERF.GT.0)GO TO 1000
      DO 55 I=1,5
      CCOST(I)=CCUST(I)+CTEMP(I)
      COSTO(I)=COSTO(I)+TEMPO(I)
55      ACOST(I)=ACUST(I)+ATEMP(I)
      EER=EER+EERIMP
C
C           COMPARE RECYCLE STREAM OS22 WITH TRECYC
C
      DO 60 I=2,20
      IF(ABS(SMATX(I,OS22)-TRECYC(I))-SMATX(I,OS22)*EPS)60,60,70
60      CONTINUE
      GO TO 90
C
C           CONVERGENCE NOT ATTAINED, INCREMENT ITERATION COUNT.
C           SAVE STREAM OS22 IN TRECYC. REPEAT ANOTHER ITERATION.
C
70      NITER=NITER+1
      IF(NITER.GT.NITMAX)GO TO 1000
      DO 80 I=2,20
80      TRECYC(I)=SMATX(I,OS22)
      GO TO 20
C
C           CONVERGENCE ATTAINED.
C
90      N=NSAVE
      IS1=IS1SAV
      OS1=OS1SAV
      OS2=OS2SAV
      OMATX(1,N)=OMATX(1,N1)
      OMATX(2,N)=OMATX(2,N1)
      OMATX(3,N)=FPS
      OMATX(4,N)=OMATX(2,N2)
      OMATX(5,N)=OMATX(4,N2)
      OMATX(6,N)=OMATX(7,N2)
      OMATX(7,N)=OMATX(17,N2)
      OMATX(8,N)=OMATX(18,N2)
      RETURN
C
C             ITERATION LIMIT EXCEEDED OR MLASS CANNOT BE ATTAINED,
C
1000      IAERF=1
      GO TO 90
      END
```

```
C
C**********************************************************************
C                                                                     *
C             UNIT PROCESS NUMBER 26                                  *
C                                                                     *
C               NON-OXIDATIVE HEAT TREATMENT                          *
C                                                                     *
C**********************************************************************
C
      SUBROUTINE HEAT
C
      INTEGER OS1,OS2
      COMMON SMATX(20,45),DMATX(20,50),OMATX(20,50),IP(50),
     2        INP,IO,IS1,IS2,OS1,OS2,N,IAERF,CCOST(5),COSTO(5),
     3        ACOST(5),DHR,PCT,WPI,CCI,RI,AF,RATIO,CKWH,YRS,
     4        CF,EER,EEP,ALAND
C
      FPRI=DMATX(6,N)
      IDIG=DMATX(7,N)
      TEMP=DMATX(1,N)
C
C      COMPUTE EFFLUENT STREAM CHARACTERISTICS
30       AS=1.3255-.00457*TEMP
      AP=1.8112-.00596*TEMP
      AD=1.9698-.00709*TEMP
      BS=1.5855-.00657*TEMP
      BP=1.8455-.00657*TEMP
      BD=1.9855-.00757*TEMP
      GND=.00163*TEMP+.1755
      GD=.00163*TEMP+.0755
      ALPHA=(1-IDIG)*(FPRI*AP+(1.-FPRI)*AS)+IDIG*AD
      BETA=(1-IDIG)*(FPRI*BP+(1.-FPRI)*BS)+IDIG*BD
      GAMMA=(1-IDIG)*GND+IDIG*GD
      SMATX(2,OS1)=SMATX(2,IS1)
      SMATX(3,OS1)=SMATX(3,IS1)*BETA
      SMATX(4,OS1)=SMATX(3,OS1)*SMATX(4,IS1)/SMATX(3,IS1)
      SMATX(5,OS1)=SMATX(5,IS1)*BETA
      SMATX(6,OS1)=SMATX(6,IS1)*BETA
      SMATX(7,OS1)=SMATX(7,IS1)
      SMATX(8,OS1)=SMATX(8,IS1)*ALPHA
      SMATX(9,OS1)=SMATX(9,IS1)*BETA
      SMATX(10,OS1)=SMATX(7,OS1)+SMATX(9,OS1)
      SMATX(11,OS1)=SMATX(11,IS1)+(SMATX(3,IS1)-SMATX(3,OS1))
      SMATX(12,OS1)=SMATX(11,OS1)*(1.-GAMMA)
      SMATX(13,OS1)=SMATX(13,IS1)+SMATX(5,IS1)*(1.-BETA)
      SMATX(14,OS1)=SMATX(14,IS1)+SMATX(6,IS1)*(1.-BETA)
      SMATX(15,OS1)=SMATX(15,IS1)
      SMATX(16,OS1)=SMATX(16,IS1)+(SMATX(13,OS1)-SMATX(13,IS1))*3.57
      SMATX(17,OS1)=SMATX(17,IS1)+SMATX(8,IS1)*SMATX(3,IS1)/
     2                (SMATX(3,IS1)-SMATX(4,IS1))*(1.-ALPHA)*GAMMA
      SMATX(18,OS1)=SMATX(13,OS1)*(.00274*TEMP-.307)
      SMATX(19,OS1)=SMATX(19,IS1)
      SMATX(20,OS1)=BETA*SMATX(20,IS1)
C
C      EVALUATE COST AND ENERGY REQUIREMENTS
      GPM=SMATX(2,IS1)*116666.7/DMATX(2,N)*DMATX(16,N)
      X=ALOG(GPM)
      CCOST(1)=EXP(5.9096-.050119*X+.073395*X**2)*1000.*.60873
     2            *CCI*RATIO
      OHRS=EXP(8.4281-.084636*X+.05961*X**2)
      OHRS=OHRS*DMATX(2,N)*52./8000.
      XMHRS=.25*OHRS
      TMSU=EXP(8.8497-.13093*X+.073644*X**2)*.6643*WPI
      XKWPY=.007*GPM/DMATX(16,N)*60.*DMATX(2,N)*52.
      ECOST=XKWPY*CKWH
      QTOT=(TEMP-20.)*.25*15./.75*GPM/DMATX(16,N)*60.*DMATX(2,N)*52.
      HPD=DMATX(2,N)/DMATX(3,N)
      IF(HPD.LT.8.)FK=2000.
      IF(HPD.LT.16.)FK=1500.
      IF(HPD.LT.24.)FK=1000.
      IF(HPD.GE.24.)FK=0.
      SPY=DMATX(3,N)*52.
      QTOT=QTOT+(12.*2000.+FK*(SPY-12.))*GPM/DMATX(16,N)*60.
      FCOST=QTOT*DMATX(4,N)/1.E6
      TMSU=TMSU+ECOST+FCOST
      COSTO(1)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU)/SMATX(2,1)/3650.
      EER=XKWPY/365.+QTOT/365.*.000293*CF
C
C      FIND COST OF SLUDGE HOLDING TANKS
      IF (DMATX(5,N) .EQ. 0.) GO TO 40
      VSHT=SMATX(2,IS1)*DMATX(5,N)*1000./7.48*DMATX(15,N)
      X=ALOG(VSHT)
      CCOST(2)=EXP(2.6252751+.484180*X+.000613*X**2+.002252*X**3)*
     2           1000.*CCI*RATIO
      X=ALOG(VSHT/DMATX(15,N))
      OHRS=EXP(5.727345+.000762*X+.098701*X**2-.006786*X**3)
      XMHRS=EXP(4.506628+.214662*X+.071402*X**2-.004681*X**3)
      TMSU=EXP(5.479939+.299282*X+.106008*X**2-.008658*X**3)
      COSTO(2)=((OHRS+XMHRS)*DHR*(1.+PCT)+TMSU*WPI)/SMATX(2,1)/3650.
C
C      FILL IN VALUES OF OUTPUT MATRIX
40     OMATX(1,N)=GPM
      OMATX(2,N)=ALPHA
      OMATX(3,N)=BETA
      OMATX(4,N)=QTOT/1.E6
      RETURN
      END
```

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